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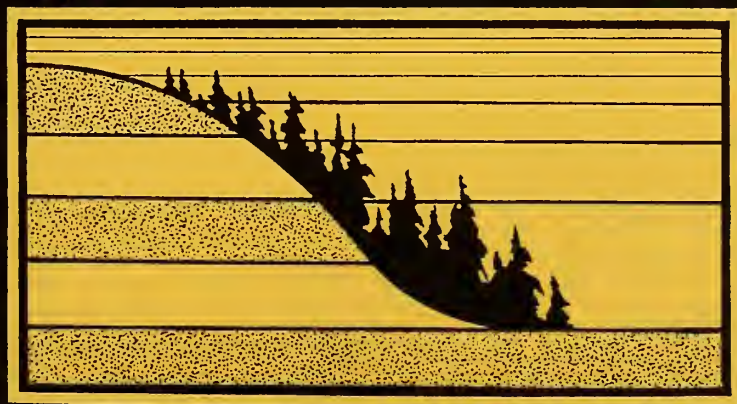
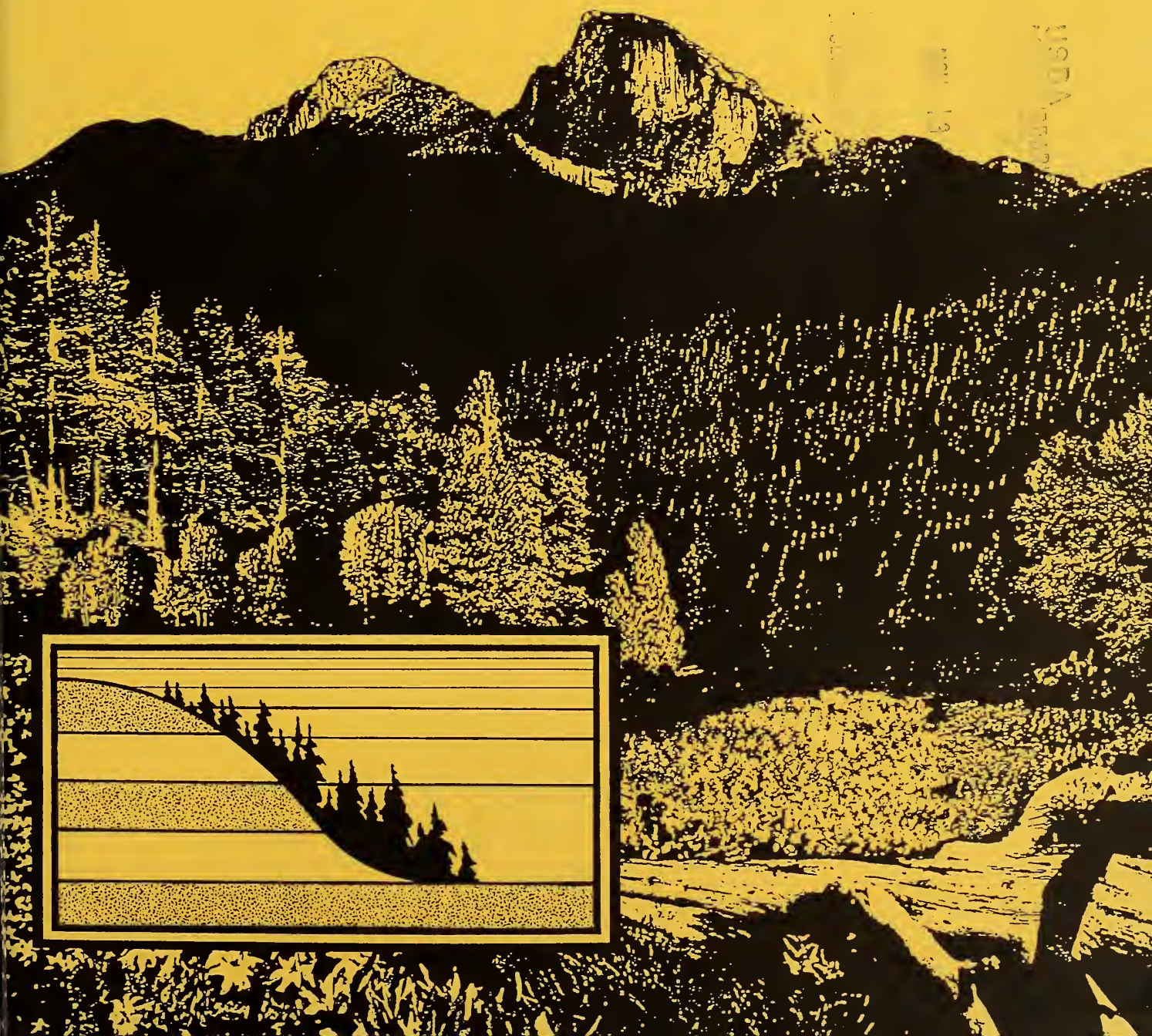
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Proceedings—Land Classifications Based on Vegetation: Applications for Resource Management



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Proceedings—Land Classifications Based on Vegetation: Applications for Resource Management

Moscow, ID; November 17-19, 1987

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Society of American Foresters

FOREWORD

Directly after Kent Houston and Ken Neiman suggested this symposium, people began asking "Why have we waited so long?" The committee members, program reviewers, speakers, and others were all enthusiastic and willing to participate. Now was a good time for a symposium on land classifications based on vegetation. Many classifications of climax plant associations for the western United States and western Canada are completed. It was time to summarize that progress and ask the question "Where do we go from here?"

The committee endeavored to invite speakers from different locations and disciplines that use land classifications based on vegetation. Topics were chosen to bring out theoretical concepts as well as practical applications of these classifications. Still, we knew that not all potential speakers could be squeezed into a 3-day session. The poster session provided a forum for additional authors, applications, demonstrations, and newly completed studies.

Sponsors of the symposium were the University of Idaho, College of Forestry, Wildlife and Range Sciences; University of Idaho, College of Agriculture; and USDA Forest Service, Intermountain Research Station. Sponsors contributed time, resources, and funding to support this effort. Other organizations which cooperated with us include the University of Montana, School of Forestry; Montana Cooperative Extension, Office of Extension Forestry; Washington State University, Department of Forestry and Range Management and Cooperative Extension; Society of American Foresters; Society for Range Management; and The

Wildlife Society, Northwest Section. We thank each of these organizations for their help. Donna Germer and Janet Yoder, University of Idaho Conferences and Enrichment Program, handled registration, fees, meeting room arrangements, and the like, and were indispensable to the success of the symposium.

A special thanks goes to Rexford Daubenmire for being our keynote speaker. At the symposium banquet, it was gratifying to learn that the Clearwater National Forest is setting aside a botanical area on Walde Mountain for study of a species discovered by Rexford Daubenmire, Dasynotus daubenmirei. Also at the banquet, David Alt, Professor of Geology at the University of Montana, gave a spectacular speech on Glacial Lake Missoula and the Spokane Floods.

Last, we thank the symposium speakers and poster presenters. Their enthusiasm and dedication are much appreciated. Authors prepared their camera-ready papers, obtained peer review, and are responsible for content. We believe they did an excellent job and hope you agree.

Frederic D. Johnson and Dennis E. Ferguson,
co-chair

Penelope Morgan,

Continuing Education and Outreach

Raymond J. Boyd

Maynard A. Fosberg

Minoru Hironaka

Kent Houston

Kenneth E. Neiman

James M. Peek

Robert D. Pfister

Edwin W. Tisdale

Charles A. Wellner

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WELCOME

Leon F. Neuenschwander

Associate Dean
College of Forestry, Wildlife, and
Range Sciences
University of Idaho

Welcome to the University of Idaho and to this symposium: Land Classifications Based on Vegetation, Applications for Resource Management. It is my privilege to welcome you to the University of Idaho which is a cosponsor of this symposium with the Intermountain Research Station, USDA Forest Service. The proceedings from this symposium will be published by the Intermountain Research Station.

The keynote speaker is Dr. Rexford Daubenmire who began this effort here in the Pacific Northwest. The 43 papers presented at this symposium represent an impressive collection of experience, expertise, and diversity. They will not only provide historical and evolutionary aspects of classification systems. The speakers will undoubtedly ask questions that future research will need to answer as classification evolves into the next century.

WELCOME

Laurence E. Lassen

You may have noticed the symposium title is in two parts--"Land Classifications Based on Vegetation" and "Applications for Resource Management." The symposium committee has recognized that there are two important items to discuss these next 3 days--development of classification systems and the transfer of information to land managers.

The Intermountain Research Station (INT) has been involved in Land Classifications Based on Vegetation for a long time. Nearly six decades ago, J. A. Larsen (1930) published a paper on climax types in the northern Rocky Mountains. The determination of climax types was thought to be controlled by topography and climate. He identified six climax types for the northern Rocky Mountains and even included a table listing species' shade tolerance, a list nearly identical to those in use today.

Of course, Rexford Daubenmire is the person who developed a classification system for the northern Rocky Mountains, a system described in his 1952 monograph and a 1968 paper co-authored with Jean Daubenmire, who is also attending the symposium. We are delighted the Daubenmire's are able to be here. Portions of the symposium will deal with habitat types, and we hope you will be pleased to see the growth in use of this classification system--something to which you devoted a considerable part of your careers.

Assistant INT Station Director, Chuck Wellner, now retired, is another person who championed the cause of land classification systems based on vegetation. In 1966, Chuck went to Rexford Daubenmire to discuss classification of forests in the Intermountain area. Graduate students of Daubenmire completed two classification projects in Wyoming under cooperative agreements as a direct result of that meeting.

Laurence E. Lassen is Director, Intermountain Research Station, Forest Service, USDA, Ogden, UT.

Research and Development cooperative agreements were initiated with the Northern Region, and then the Intermountain Region, of the Forest Service. INT provided leadership under the direction of Bob Pfister, and the Forest Service Regions funded a good deal of the project and provided field crews. A large project got under way in 1971 in Montana's forests. Within a year, range and shrubland was being classified under the direction of Walt Mueggler. About 2 years later, Bob Steele, under Pfister's direction, was spearheading an effort in central Idaho. INT scientists continue this effort and have published many general technical reports describing land classification systems in the Intermountain West.

Equally important is the second part of the title, "Applications for Resource Management." A researcher's job is incomplete until ideas and techniques are put into practice. Part of that job is accomplished through publications. The proceedings of this symposium will be recorded in an INT General Technical Report. A continuing part of the job will be through participation in future workshops and in individual and small-group consultations with resource managers.

Of course, another way INT helps get research results applied is in helping to sponsor symposia like this one. This symposium is a forum for us to exchange ideas and share experiences. You will learn what has been done in the field of land classifications based on vegetation, how the systems are used, what problems had to be overcome, how we could be doing some jobs better, and what remains to be done.

Stay tuned for an exciting program.

REFERENCE

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THE ROOTS OF A CONCEPT

Rexford Daubenmire

ABSTRACT: Some experiences which led to the development of the Habitat Type concept are described. Also the publications of some early workers who championed principles included in the Habitat Type are briefly reviewed.

INTRODUCTION

When I was invited to give some introductory remarks to this symposium, I welcomed the opportunity to participate in discussions of a subject which was, for a long time, a major focus of my research interest. But later, on seeing the list of assigned subjects, I had second thoughts, realizing that it might be difficult to say anything without impinging on the turf of other symposium speakers. This problem seemed solved, however, when it was suggested that I simply outline briefly the origin and development of the Habitat Type (HT) concept.

Most of my schooling was east of the Mississippi River, and during graduate training at the University of Minnesota I took a course in Plant Geography. There the classic publications of C. H. Merriam on southern Idaho and Arizona were given considerable emphasis. So in 1936, when I was appointed Assistant Professor in the Department of Botany at the University of Idaho, I expected the mountain vegetation here to be somewhat similar to the schematic diagram of Merriam's (1890) system (fig. 1) that was well known at that time. But my first trip into the foothills of the forested mountain which rises from the prairie just a few miles north of this city proved quite disconcerting. I had scarcely left the dry prairie and entered the forest when I saw Engelmann spruce growing along creek margins. Then farther into the mountain, ponderosa pine was seen extending up ridge summits to near the top, approximately 3,000 ft (600 m) higher. Obviously a lot of work would be needed if I was ever to gain an understanding of this unexpected reversal of Merriam's altitudinal relationships.

Paper presented at the Symposium "Land Classifications Based on Vegetation: Applications for Resource Management," Moscow, ID, November 17-19, 1987.

Rexford Daubenmire is Professor Emeritus of Botany, Washington State University, Pullman, WA; currently living in Sorrento, FL.

INFERENCES FROM INVENTORIES

During my doctorate research in Minnesota I had developed a keen appreciation for the significant inferences that can be drawn from a table that represents a complete inventory of the trees in a sizable portion of a homogeneous forest stand. The distribution of the size classes for each species, serving as a crude indicator of relative age within that species, tells much of the past history of that stand, as well as suggesting its future status. So on my first field trip with students into the nearby mountains, I had the class lay out a large plot in an old clearcut, then asked them to divide up and assemble an inventory of all the trees, keeping separate the size-class data for each species. Table 1 is a summary of the data.

To judge from the relatively large individuals, most of the species obviously had considerable seedling success early in the regeneration cycle. Some of them probably invaded quickly, but the seedlings of these species had stopped surviving years ago. It could be predicted that, barring another disturbance, these trees would eventually lose representation on the site.

Seedlings of one of the species, however, had for some time continued to be quite successful despite the closing of the canopy, so it might eventually be left as the sole dominant of the overstory. The absence of western redcedar in the largest size classes could signify either a lateness of its invasion, or perhaps just a slower rate of growth in individuals that had actually arrived as early as those species represented by large trees. A hypothesis that old western redcedar trees could alone form the tree canopy was later proven by finding a number of stands scattered from Montana to British Columbia to Washington, one even on the same mountain that the class had sampled.

By continuing to emphasize seedling success rather than the composition of the current tree dominants, the south slope of the same mountain was found to provide environments suitable to support only four potential tree dominants (Daubenmire 1980). These four types of environment later proved to represent segments of a soil-moisture continuum ranging from one especially conspicuous on ridge crests where a short dry period developed late in summer, to the fourth that is best developed on the lower slopes of ravines where the soil profile remains moist the year around. The spruce and ponderosa pine distributions, which puzzled me at first, now had a rational explanation.

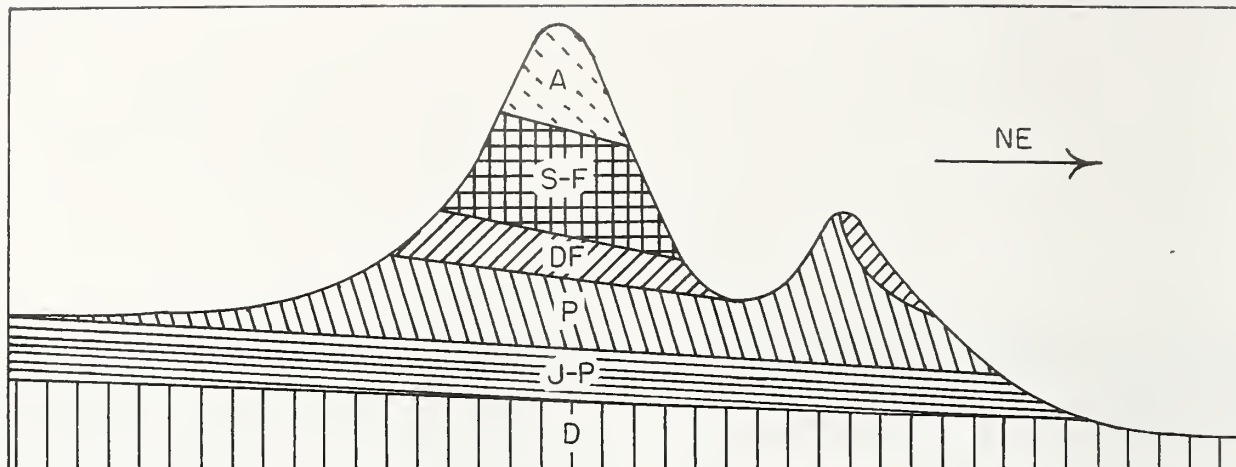


Figure 1--Diagram of vegetation as related to topography in northern Arizona, after Merriam (1890).
A = Alpine, S-F = Spruce-fir, DF = Douglas-fir, P = Ponderosa pine, J-P = Juniper-pinon, D = Desert.

Later, as the data for a number of western redcedar stands accumulated, it became clear that essentially pure stands of this tree occur in very contrasted environments. On well-drained sites the tree has a sparse undergrowth of low shrubs and herbs. But the same tree may dominate swamps where the undergrowth includes a complete cover of the thorny Devil's club. This phenomenon, with one type of climax tree cover embracing different kinds of environment as shown by differences in the undergrowth, proved to be common. Then the reverse phenomenon was also found repeatedly, that is, with the same undergrowth type occurring beneath different climax trees (Daubenmire and Daubenmire 1968). Overstory types (table 2) here aligned across the top, simply reflect segments of a continuum from warm-dry at the left, to cold-wet on the right. The principal dominants of the undergrowth types to be found in each of the moisture-temperature ranges as indicated by trees are listed down the left side. Climax undergrowth types obviously respond differently to the complex environmental mosaic--in places their limits correspond with limits critical for the trees, but elsewhere they

show remarkable insensitivity to tree limits. Soils and microclimates seem relatively more important for the ground vegetation, and so it adds a second dimension to an ecologically based vegetation classification. Each distinctive combination of overstory plus undergrowth, defines the extent of environment that has a high degree of homogeneity among all the land areas supporting that combination. In other words, the potential vegetation defines distinctive Habitat Types (HTs).

Since overstory types reflect moisture-temperature relations almost alone, they facilitate correlation among different parts of the Rockies, which would be rather difficult using undergrowth for the first level of correlation.

EARLIER CLASSIFICATIONS

Now I would like to relate the HT to some earlier forest classifications that had been developed elsewhere.

Table 1--Tree density/750m², Crumarine Creek, Latah County

Species	Diameter (at breast height) classes				
	0-1 dm			1-2	2-3
	Under 0.5 dm			3-4	4-5
	Under 1 m tall	Over 1 m tall	Over 0.5 dm		
Western redcedar	¹ 20	53	42	30	2
Grand fir		7	28	38	10
Western larch			6	13	5
Mountain maple			1	27	
Western white pine				5	10
Paper birch				2	
Engelmann spruce				1	1
Douglas-fir					3

¹All representing layered branches.

²All from one stump; represent maximum size for species.

Table 2--Undergrowth communities found in association with climax trees of overstory in northern Idaho-eastern Washington

Dominant plants of undergrowth types	Overstory dominants					
	Ponderosa pine	Douglas -fir	Grand fir	Western redcedar	Western hemlock	Subalpine fir Mountain hemlock
Needle-and-thread	+					
Idaho fescue	+					
Bitterbrush	+					
Rose and Snowberry	+	+				
Ninebark	+	+				
Pinegrass		+				
Lady fern				+		
Devil's club				+		
Mountain box			+	+	+	+
Grouseberry					+	
Beargrass					+	+
Fool's huckleberry					+	+

Vegetation classification is indeed a very old concept. It probably got started as soon as hominoids developed language which enabled them to convey abstract thoughts to one another. This is suggested by the fact that most primitive tribes today have a vegetation classification for their own territories. They distinguish ecosystem types by their vegetation, and have learned what useful products may be obtained from each.

As Caucasian civilization developed, vegetation classification as a cultural attribute tended to atrophy, for with the exception of a continuing dependence on wood for fuel, most basic needs came to be furnished by crops and livestock. Eventually, increasing demands for wood for the construction of buildings and ships as well as for fuel led to sufficient forest depletion that tree planting became necessary. It was obvious that each tree species does not grow equally well in all vegetation types where it occurs or may be planted, and vegetation classification appeared to have potential value.

At the beginning of our century, the Russian forester G. F. Morosov was teaching and publishing work emphasizing the indicator significance of vegetation. Written in the Russian language, his publications seem to have gained little more than local attention.

In 1926 the Finnish forester A. K. Cajander, apparently inspired by Morosov's work, presented a classification of Finland's forest communities. His study, originally written in the Finnish language, was unique in that it ignored species composition in the tree stratum. It was based entirely on just the undergrowth shrubs, herbs, and cryptogams. Such a perspective may have some justification in that Finland is small, is completely blanketed with glacial drift, and is topographically rather uniform. His classification gained considerable interest, especially after translation, for he demonstrated its value in forest management.

Two years after Cajander's classic publication appeared, one of Morosov's students, V. N. Sukatchev (1928), presented a classification for the extensive belt of spruce forest across

northern Russia. The name of each of his forest types combined the genus of the forest tree with the name of the most diagnostic plant in the undergrowth. Although this appears to have been the first time more than one vegetation stratum was used in naming a forest community, the system otherwise was not basically different from that of Cajander. Since he did not distinguish between the western spruce forests of *Picea abies* and the eastern spruce forest of *P. obovata*, this was just a classification of undergrowth. Although a Russian, Sukatchev published in a prestigious British journal, yet his use of binomials in referring to different combinations of vegetation strata gained no support from subsequent forest classifiers.

On our side of the Atlantic, F. E. Clements and H. C. Cowles were at the same time vigorously pushing a viewpoint that succession should be the center of interest in plant ecology. Europeans had treated their forest types as being essentially static, or climax. In the American view all but one of the extremely diverse communities in a large area are essentially seral stages that lead to the same climax type. Clements' and Cowles' ways of explaining what motivated such great transformations differed, but both were committed to this, the monoclimate hypothesis. Both men were good salesmen and through their advocacy of it, the hypothesis gained wide acceptance in North America. But in Europe, succession continued to get negligible attention until eventually it was given a new perspective by A. G. Tansley's (1935) contention that there may be several equally stable kinds of communities in a given landscape mosaic, if that landscape includes several distinctive kinds of environment. This is the polyclimax concept, which finds favor with perhaps most ecologists today.

Although a number of continental Europeans have proposed still different approaches for vegetation classification, a combination of national pride and personal ego prevented objective testing of their relative merits. Indeed, there was so much discord among vegetation investigators at science conventions early in this century that classification became generally discredited as a field deserving development in

community ecology. Nevertheless, a few of the older proposals still have a following. Cajander's approach has been advocated in Montreal and in New York State, and Braun-Blanquet's method has gained acceptance in many places outside its home grounds in the Alps.

HT CONCEPT SURVIVAL

I suspect that had I not documented the value of HTs for predicting tree growth and mistletoe susceptibility (Daubenmire 1961), with a forester then testing the approach independently and finding it useful (Roe 1967), the HT concept too might have passed into virtual oblivion.

But the HT approach has met with some rebuffs. For example, the Soil Conservation Service once asked me to give a series of lectures on synecology to a group of field personnel which the Service brought together each year in Lincoln, Nebraska. The person organizing this session, knowing of my interest in HTs, discretely suggested that I devote minimal time to this subject, because, he said, it applied to only the region in which it was developed! Apparently he did not think an ecological principle was involved, and apparently he did not like my interpretation of the word "minimal," for I was not asked back next year. Despite his opinion, the concept has been used widely in the Rocky Mountains, in deciduous forests in Michigan and Ohio, and in steppe vegetation. It seems to be a fundamental perspective that is useful wherever natural vegetation is still reasonably intact.

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CLASSIFICATION OF HABITAT TYPES IN THE WESTERN UNITED STATES

Charles A. Wellner

ABSTRACT: Progress in developing land classification by vegetation habitat types in the western United States from the time Daubenmire published his concept of habitat types to the present is described by three periods: through 1970, 1971 through 1980, and 1981 through 1987. In the initial period, ecologists and land managers became familiar with the concept, tested it, and developed classifications for limited areas. During the 1971 through 1980 period, progress in developing habitat type classifications increased dramatically. The number of published classifications was even greater during the 1981 through 1987 period because of work begun in the previous period and new classification programs. The USDA Forest Service has accounted for most of the progress through in-service classification programs and cooperative agreements with university scientists. Because foresters badly needed an ecologically based land classification, they readily accepted the habitat type system. As a result, classifications have been developed for most of the forest land in the western United States. Classification by habitat type of non-forest land is progressing more slowly. The development of classifications by habitat types is far from complete in the western United States. Classifications need to be developed for forest lands not yet classified, and the non-forest lands especially need attention. Existing classifications need to be better correlated. Seral communities within many habitat types need to be classified, their successional pathways determined, and the management implications assessed. Finally, habitat types need to be better fitted into an overall land classification framework.

INTRODUCTION

During the last 20 years, we have witnessed great interest and progress in developing classification systems that relate or integrate knowledge needed for land management (Bailey 1982; Brown and others 1980; Driscoll and others 1984; Pfister and others 1973; Wertz and Arnold 1972). This has come about through increasing knowledge of processes and functioning of plants, animals, and ecosystems; greater management experience; and increasing

interest in public lands and their management; all sharpened by a number of Congressional acts that mandate ecological management of Federal forest and range lands. Attempts to relate and integrate knowledge of climate, landforms, soils, and vegetation both existing and potential--all needed in land management--are ongoing.

I will confine this paper to the remarkable extension through the western United States of Rexford Daubenmire's concept of land classification by vegetation habitat types. A number of ecologists, including Pfister (1977, 1982), Pfister and Arno (1980), and Franklin (1980) have previously reviewed progress in ecological classification of forest vegetation. This account will attempt to bring the extension of classification by habitat types up to date. I acknowledge the help of papers of the foregoing ecologists, and a number of people, especially the Regional Forest Service ecologists--Wendel Hann, Barry Johnston, Will Moir, Al Winward, David Diaz, and Fred Hall--and several Idaho ecologists, especially Ed Tisdale, Min Hironaka, and Bob Steele. And my apologies for omissions and errors that occur in my account.

Following are some sideboards to this review. Theory and methodology of habitat type classification are not discussed, mainly because these topics have been described by a number of scientists, especially Daubenmire (1952), Daubenmire and Daubenmire (1968), Franklin and others (1970), Hall (1980), Moir and Ludwig (1983), Pfister and Arno (1980), Schlatterer (1983), Stewart and Hann (1983), and Pfister (this proceedings). Classifications by range sites and classification of riparian vegetation are not included. However, classifications using terminology other than habitat types, such as plant associations that are based on potential climax vegetation to classify land areas capable of producing similar plant communities at climax, are included. Also included are classifications of seral vegetation into community types that explain succession within habitat types and the management implications involved.

BEFORE DAUBENMIRE

Let us start with the forest classification situation in the northern Rocky Mountains before Daubenmire. From an ecological standpoint, it was simply chaos. We used broad forest cover types to classify forests. The Society of American Foresters cover types was one classification in use. The Forest Service used a similar but slightly different classification of existing forests for forest inventory and timber sales purposes. These classifications in some instances

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accommodated economic values. For example, the western white pine type was defined as any stand that contained 15 percent or more western white pine and the ponderosa pine type included any stand that contained 25 percent or more ponderosa pine. Western larch and Douglas-fir were often classified together as Larch-Fir because wood properties and values of the two species were similar and they sold in the same market. Classification of forests was largely for the purpose of forest regulation, timber sales, and to determine the timber supply situation. Classification served the purposes intended but was not geared to ecological management of forest lands. This did not mean that foresters lacked understanding of the successional role of forest species. Tolerance of tree species and their role in succession were known early in the century and were described in numerous publications, but this knowledge did not enter to any great extent in classification.

The lack of classification based on the ecology of the forest land led to serious problems for forest research scientists and forest managers. For example, the silvicultural research program in the Intermountain Research Station was organized by broad forest types. Although the site conditions under which research was conducted were described in publications, results often were considered by managers to apply broadly. When land managers tried to apply research results, at times they found them unsatisfactory for their conditions. As a result, the research was questioned. This happened often enough that both research scientists and forest managers realized an ecologically based classification system was needed. The need became especially critical after World War II when intensive management of National Forests increased markedly, and we were able to expand our research programs to most major ecosystems.

In the northeastern United States, Westveld (1951) had expressed the need for an ecological classification as a guide to better silviculture. He proposed a classification for spruce-fir and northern hardwood forests based on climax tree species and indicator understory species to arrive at site-types. In essence, Westveld proposed a classification that Daubenmire a year later termed habitat types. However, Westveld's proposal apparently did not gain acceptance.

1952 THROUGH 1970

When Daubenmire (1952) published his paper on forest habitat types, many foresters in northern Idaho were interested. We began trying the classification in northern Idaho forests. The 1950's were a period of becoming familiar with the classification, testing it, and determining our ability to use it. By the early 1960's, a number of us were convinced that classification by habitat types was a system that would meet research and management needs. Research silviculturists in Moscow, ID, and Missoula, MT, began using habitat types to help describe the ecological situation of their studies and in reporting results and recommending practices. However, the problem facing us was that we had a classification only for northern Idaho and northeastern Washington.

We tried to extrapolate the classification to the east and south, but this was not satisfactory. The need was to extend the classification to all forest and range lands in the Intermountain West. I talked with Blair Hutchinson and Jack Wikstrom, both responsible for Forest Survey in Rocky Mountain States, about including habitat types in an upcoming resurvey of forest lands in northern Idaho, explaining the benefit of habitat types in the management of all resources. They were enthusiastic. So was Sam Evans, the Northern Region Silviculturist. When the resurvey was completed, Glenn Deitschman, Project Leader of the Intermountain Station's silvicultural research project in Moscow, checked survey plots to determine the accuracy of habitat type determinations. When he reported that only 50 percent were classified correctly, we were dismayed! These discouraging results pointed up the need for intensive training in habitat type classification not only for inventory crews but for all those engaged in forest management. This emphasized the need for intensive training in the habitat type concept by university and Forest Service ecologists and the inclusion of habitat type classification in university courses.

A major problem still remained: we had a classification developed for only a limited area--how to finance and staff an extension of the classification remained. I visited Dr. Daubenmire on February 2, 1966, to discuss the problem with him. He suggested that we fund graduate students, each of whom would develop a classification for vegetation in a specified area as a dissertation subject. We were able to get funds from the Washington Office to help do this and decided to leapfrog the effort to western Wyoming. The result was Reed's (1969) thesis on vegetation of the Wind River Mountains. Later a similar arrangement was used to fund Cooper's (1975) graduate work in northwestern Wyoming.

In the mid-1960s, the Intermountain Region of the Forest Service was having problems obtaining adequate regeneration of Engelmann spruce. The Regional Forester, Floyd Iverson, halted spruce sales until we determined how to regenerate the high-elevation spruce forests. We assigned Arthur Roe, Project Leader of a silvicultural research project in Missoula, to determine whether and where research was needed. He and Allan Dahlgreen, in charge of regeneration and planting in the Intermountain Region, examined problem areas and determined that existing knowledge, if followed, would take care of regeneration problems over much of the spruce type, except in southern Utah. Bob Pfister, who had taken Roe's place as Project Leader of silvicultural research, was assigned to the research job in southern Utah. His work pointed to the need for the classification of spruce sites on an ecological basis. As a result, he developed a habitat type classification of high-elevation forests of Utah as his Ph.D. dissertation working under Dr. Daubenmire. We were modestly on our way in developing a habitat type classification for forests of Utah.

Table 1 shows habitat type classifications through 1970 in western United States and location of classification efforts is shown in figure 1.

Table 1--Classifications of habitat types completed or in progress by 1970 in the western United States, listed chronologically by Forest Service region. The general location of listed studies is shown in figure 1. See references for complete citation

Forest Service region	References
Northern (Montana, northern Idaho, North Dakota, & northwestern South Dakota)	Daubenmire 1952 Mueggler 1965 Daubenmire and Daubenmire 1968 Daubenmire 1970
Rocky Mountain (Colorado, Kansas, Nebraska, South Dakota, and eastern Wyoming)	Steen and Dix 1970 ¹
Intermountain (Nevada, Utah, western Wyoming, and southern Idaho)	Reed 1969 Pfister 1972 ¹
Pacific Northwest (Oregon and Washington)	Driscoll 1964 Corliss and Dyrness 1965 Bailey 1966 Dyrness and Youngberg 1966 Franklin 1966 Hall 1967

¹Initiated, but not completed.

Daubenmire and Daubenmire (1968) had completed a classification of forest sites in northern Idaho and northeastern Washington, and Daubenmire (1970) had developed a classification of steppe vegetation of eastern Washington. Mueggler (1965) had studied succession in certain western redcedar and western hemlock habitat types in northern Idaho. Reed (1969) had completed his Ph.D. dissertation on forest vegetation of the Wind River Range in Wyoming. Pfister (1972) had completed field work on his classification of high-elevation forests of Utah but had not yet completed his dissertation. Steen and Dix (1970) were working on classification of subalpine forests of Colorado.

In the Pacific Northwest Region of the Forest Service, Driscoll (1964) had developed vegetation-soil units in the central Oregon juniper zone, and Franklin (1966) had completed his dissertation on subalpine forests of the southern Washington Cascade Range. Students, mainly of C. E. Poulton at Oregon State University, who was a 1953 graduate student of Daubenmire's, were developing habitat type classifications for limited areas in Oregon: Corliss and Dyrness (1965) on the coast, Bailey (1966) in the southern coastal area, and Dyrness and Youngberg (1966) for ponderosa pine forests of central Oregon. Hall (1967) completed a dissertation working under Poulton on vegetation-soil relations as a basis for resource management in the Ochoco National Forest. Hall modified the habitat type concept to include not only potential but also seral vegetation, soils, landforms, and management implications.

The period 1952 through 1970 was highlighted by further development of the concept of classification by habitat types by Daubenmire, scientists and land managers becoming familiar with the concept and testing it at various locations, and especially the training of young scientists in the concept, mainly as graduate students of Daubenmire and Poulton, but some elsewhere. Such a cadre of trained ecologists was crucial to extend the concept. Also, the need to train scientists and land managers was recognized, and training programs were begun. Extension of the habitat type concept was on its way by 1970, but classifications had been developed for only a limited area of land.

1971 THROUGH 1980

Table 2 lists completed classifications by Forest Service regions during this period. Figure 2 shows where they occurred.



Figure 1--Habitat type classifications in the western United States through 1970. Numbers refer to the year published and letters to the authors, as follows: BA-Bailey, CD-Corliss and Dyrness, DR-Driscoll, DA-Daubenmire, DD-Daubenmire and Daubenmire, DY-Dyrness and Youngberg, FR-Franklin, MU-Mueggler, PF-Pfister, RE-Reed, and SD-Stein and Dix. Letters without numbers refer to classifications under way. Full citations of publications are given in the references.

Table 2--Classifications of habitat types completed in the period 1971-1980 in the western United States, listed by Forest Service region, author, and year completed. The general location of listed studies is shown in figure 2. See references for complete citation

Forest Service region	References
Northern	Mueggler and Stewart 1980, Pfister and others 1977, Roberts 1980, Steele and others 1976.
Rocky Mountain	Boyce 1977, Bunin 1975, Hoffman and Alexander 1976, 1980, Terwilleger and Tiedeman 1978, Tiedeman 1978, Tweit and Houston 1980, Wirsing 1973, Wirsing and Alexander 1975.
Southwestern (Arizona and New Mexico)	Carmichael and others 1978, Hanks and others 1977, Layser and Schubert 1979, Moir and Ludwig 1979.
Intermountain	Cooper 1975, Henderson and others 1976, 1977, Hironaka and Fosberg 1979, Lewis 1971, 1975, Pfister 1972, Reed 1971, 1976, Schlatterer 1972, Steele and others 1975, 1976, 1977, Zamora and Tueller 1973.
Pacific Southwest (California)	Sawyer and Thornburgh 1977.
Pacific Northwest	Dyrness and others 1974, Hall 1973, Henderson 1973, Hines 1971, Hopkins 1979a, 1979b, Tisdale 1979, Volland 1976, Winward and Youtie 1978.

By 1970 in the Intermountain Station, we recognized that a major and costly program was needed to extend habitat type classification as rapidly as possible. Our solution was to assign forest classification as a responsibility of our ecosystem research project. We assigned Bob Pfister as Project Leader and in 1971 entered into a cooperative research and development program with the Northern Region of the Forest Service to develop a habitat type classification for Montana forests. Pfister recruited Steve Arno as an assistant, and the classification program was on its way. The intention was to develop classifications of habitat types and to follow this with classifications of seral communities within habitat types, determine their successional pathways, and assemble a more complete assessment of management implications. Unfortunately, after development of habitat type classifications for several areas, the program lost much of the support needed to accomplish the latter objectives. However, Pfister and others

(1977) had included certain management implications in the original classifications.

Additional programs started a year later. The Northern Region requested a similar program on classification of grasslands and shrublands of western Montana. Walter Mueggler, a Project Leader in range research at Bozeman, MT, was assigned by the Intermountain Station to lead this program. A cooperative program between the Station and the Intermountain Region was started in 1972 to develop classification for forest lands in central Idaho. Robert Steele, a student of Fred Johnson at the University of Idaho, was recruited by Pfister to lead this effort as a member of Pfister's unit.

Procedures in these programs evolved with the programs but were generally similar from reconnaissance to the final publications. Sampling methods had been developed by the Daubenmires (1968), Franklin and others (1970), and modified by Pfister and his staff (Pfister and Arno 1980) to facilitate rapid development of a habitat type classification. Analysis of data was similar to that used by Dyrness and others (1974). Preliminary classifications were distributed, and land managers were urged to try them and to comment. After 2 or more years, a review draft incorporating comments and new data was prepared and distributed to use and review. Finally,

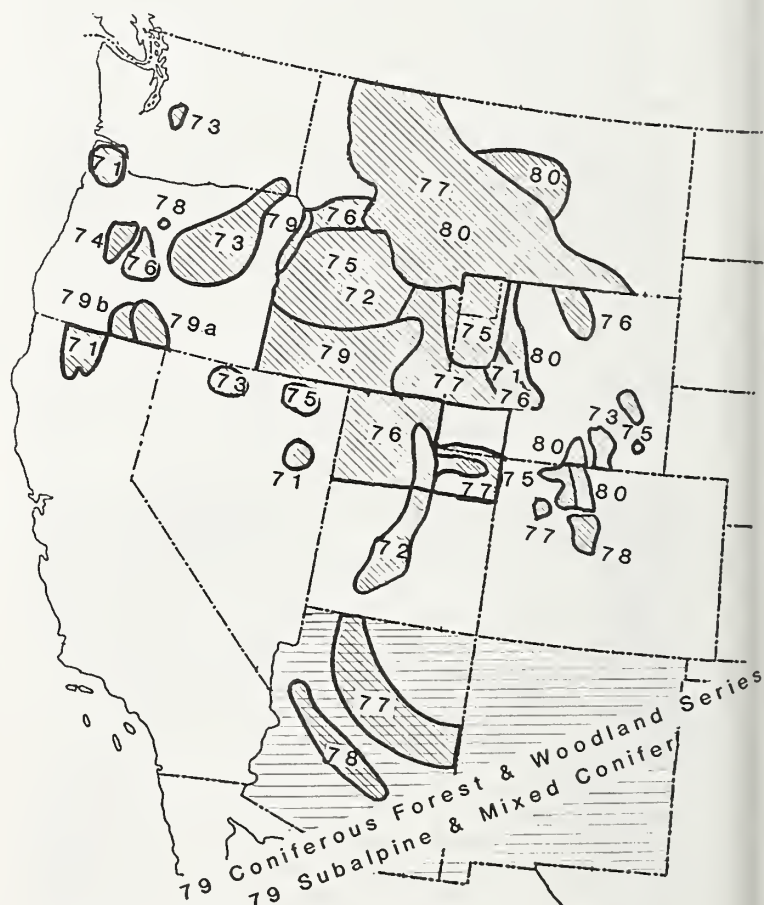


Figure 2--Habitat type classifications in the western United States published during the period 1971 through 1980. Numbers refer to year of publication.

a classification for publication was prepared. Pfister and others (1977) completed a habitat type classification for much of the forest land in Montana, and Roberts (1980) added classification for an additional area in eastern Montana. Mueggler and Stewart (1980) completed and published their classification of grasslands and shrublands of western Montana. Steele and others (1976) issued a preliminary report on classification of forests in the Nez Perce National Forest of northern Idaho. Schlatterer (1972) made preliminary studies of plant associations of central Idaho, and Steele and others (1975) issued a preliminary report on a habitat type classification of central Idaho forests before beginning work in eastern Idaho and western Wyoming and doing the same there (Steele and others 1977). Hironaka and Fosberg (1979) issued a preliminary report on non-forest habitat types in southern Idaho. Cooper (1975) completed his dissertation classification of northwestern Wyoming forests, and Reed (1971, 1976) published his dissertation on forest habitat types of the Wind River Mountains in Wyoming. Pfister (1972) completed his dissertation on classification of high-elevation forests of Utah. Henderson and others (1976) issued a preliminary report on classification of forests in northwestern Utah and another (1977) for forests of the Uinta Mountains. In Nevada, Lewis (1971, 1975) reported on plant associations of two mountain areas, and Zamora and Tueller (1973) published on sagebrush habitat types.

During the 1971 through 1980 period, a number of habitat type classifications were completed in the Rocky Mountain Region, mainly classifications of forests lands but with some exceptions. Work by Boyce (1977), Bunin (1975), Hoffman and Alexander (1976), Terwilliger and Tiedeman (1978), Tiedeman (1978), Tweit and Houston (1980), Wirsing (1973), and Wirsing and Alexander (1975) was reported.

The Southwestern Region also made a start. Hanks and others (1977), Carmichael and others (1978), Layser and Schubert (1979), and Moir and Ludwig (1979) all contributed to the classification program of the Southwestern Region.

The Pacific Southwest Region had one report by Sawyer and Thornburgh (1977) of vegetation types in the Klamath Mountains of California.

In the Pacific Northwest Region, zone ecologists under the direction of Fred Hall began development of classifications of National Forests, and a few reports were issued by the end of the period. These included Hall (1973), Henderson (1973), Hopkins (1979a, 1979b), and Volland (1976). In addition to areas classified by the zone ecologists, other areas were classified by Dyrness and others (1974), Tisdale (1979), Hines (1971) and Winward and Youtie (1978).

In summary, the 1971 through 1980 period was one of major accomplishments in Montana and Idaho and a beginning of efforts with some completions in several other states. Extension of habitat type classifications was by major Forest Service in-service programs and by contracts for smaller areas and an assortment of smaller efforts. Evolution of methodology for rapidly getting the job done marked the period, too.

1981 THROUGH 1987

Table 3 provides a listing of classifications completed during this period, and figure 3 shows where they occurred. The period was marked by a large number of completed classifications--too many to reference in the discussion that follows. New classifications were developed for grasslands and

Table 3--Classifications of habitat types completed in the period 1981-1987 in the western United States, listed by Forest Service region, author, and year completed. The general location of listed studies is shown in figure 3. See references for complete citation

Forest Service Region	Reference
Northern	Arno 1985, Cholewa and Johnson 1983, Cooper and others 1987, Hann 1982, Hansen and Hoffman 1986, Hirsch 1985, Zamora 1982.
Rocky Mountain	Alexander and others 1986, Baker 1982, 1983, DeVelice and others 1986, Hess 1981, Hess and Wasser 1982, Hess and Alexander 1986, Hoffman and Alexander 1983, 1987, Komarkova 1986, Steinauer 1984, Thilenius and Smith 1985.
Southwestern	Alexander and others 1984a, 1984b, 1987, Alexander and Ronco 1987, DeVelice and others 1986, Fitzhugh and others 1987, Hanks and others 1983, Kennedy 1983, Larson and Moir 1986, Moir and Carleton 1987, Muldavin and others 1987a, 1986b, USDA Forest Service 1987a, 1987b.
Intermountain	Gregory 1983, Hironaka and others 1983, Jensen 1987, Mauk and Henderson 1984, Mooney 1985, Mueggler and Campbell 1982, 1986, Nelson and Jensen 1987, Steele and others 1981, 1983, Steele and Geier-Hayes 1983, 1984, 1985a, 1985b, 1986, 1987, Tueller and Eckert 1987, Youngblood and Mueggler 1981, Youngblood and Mauk 1985.
Pacific Southwest	None
Pacific Northwest	Atzet and Wheeler 1984, Brockway and others 1983a, 1983b, Hall 1987, Halvorson and others 1986, Hemstrom and others 1982, 1987, Hemstrom and Logan 1986, Henderson 1982a, 1982b, 1984, Henderson and Peter 1981a, 1981b, Hopkins and Kovalchik 1983, Johnson 1982, Johnson and Simon 1987a, 1987b, Lillybridge 1984, Tisdale 1986, Topik and others 1986, Volland 1985, Williams and Lillybridge 1983, 1987, Yarie 1983.

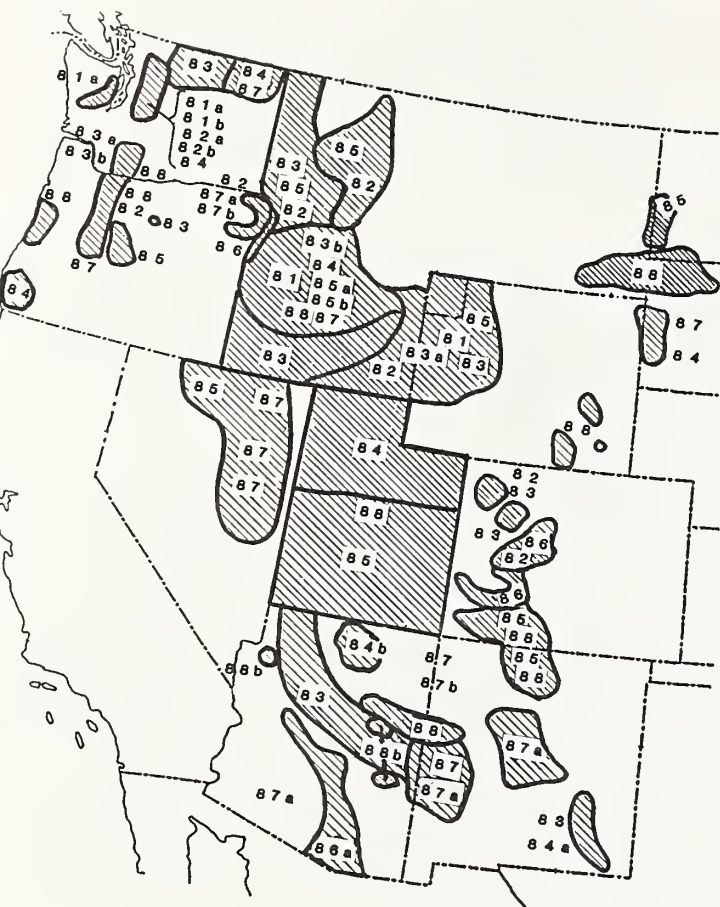


Figure 3--Habitat type classifications in the western United States published during the period 1981 through 1987. Numbers refer to year of publication.

shrublands in the Custer National Forest in southeastern Montana and the adjacent Dakotas. The work in Montana and Idaho was devoted largely to successional studies and classifications of seral stages of certain habitat types. The classification of northern Idaho forests was redone to include habitat types missed in the original classification and to divide certain broad habitat types. Classifications for both coniferous and aspen forests in Utah were completed.

Table 4--Number of habitat type classifications completed in the western United States, by time periods and Forest Service regions

Forest Service region	Through 1970	1971-1980	1981-1987
Northern	4	4	7
Rocky Mountain	0	9	11
Southwestern	0	4	14
Intermountain	1	14	19
Pacific Southwest	0	1	0
Pacific Northwest	6	9	24
Totals	11	41	75

Sagebrush and other mountain shrub vegetation was given attention in Nevada. Classification of most forest lands in Wyoming, Colorado, New Mexico, and Arizona was completed. Most of the classifications in Washington and Oregon were by Hall's zone ecologists. In brief, an impressive number of classifications were completed, many of them for National Forest land.

Table 4, which lists the number of completed classifications by time periods and Forest Service Regions, indicates the steady increase in classification effort.

DISCUSSION

Figure 4 attempts to show habitat type classifications to date. It is somewhat misleading because classification of all lands in areas showing classification is not complete. Even Idaho, which probably is most complete, lacks classifications for alpine areas, certain mountain shrub communities, most wetlands, and salt-desert shrub habitats. In addition, although a start has been made, classification of seral stages within habitat types, their successional pathways, and a more complete assessment of management implications needs to be completed for most habitat types.

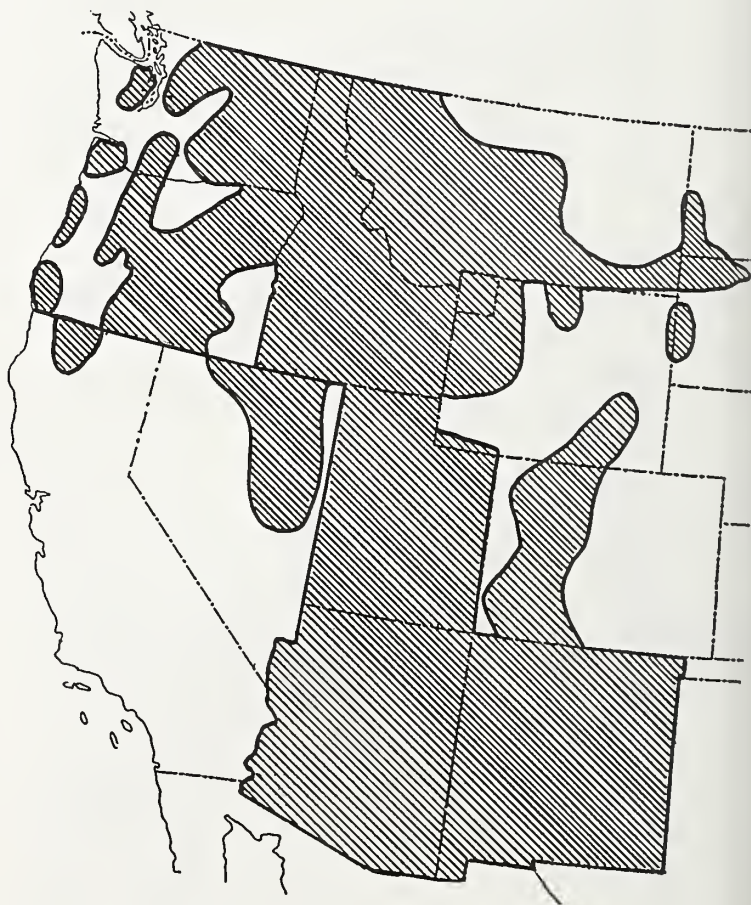


Figure 4--Areas in the western United States where vegetation has been partially or completely classified by habitat types.

Major gaps in classifications in the Northern Region include forests and grasslands in eastern Montana, and alpine areas.

Robert Alexander (1985) has summarized major habitat types, community types, and plant communities in the Rocky Mountains, and Barry Johnston (1987) has published a detailed manual of plant associations of the Rocky Mountain Region of the Forest Service. Johnston (1983) reported a critical need to develop plant association classifications for non-forest lands using a multifactor methodology. He is concerned about incompleteness of some contract classifications and the correlations needed and required between classifications. He prefers complete classifications of all lands in any unit rather than separate classifications for forests, shrublands, grasslands, etc.

Moir (1987) reported that major gaps in classifications for the Southwestern Region are grasslands, deserts, chaparral, and alpine.

In the Intermountain Region, major gaps are pinyon-juniper, salt-desert shrublands, and alpine areas. Classifications are needed for non-forest lands in Utah and Nevada. Winward (1987) stated that the Intermountain Region will depend on the Pacific Southwest Region to develop classifications for Intermountain Region land in California. Duane Lloyd of Intermountain Station informed me that Richard Everett, with Intermountain Station in Reno, is devoting much of his time to the difficult task of developing a classification for pinyon-juniper lands.

Allen and Diaz (poster paper, this proceedings) describe a Federal-State long-term program, begun in 1983, to develop a classification system that will identify ecological types in California. An inter-agency group meets regularly to assist this program. They will have draft guides for several target types ready by early 1988 for field testing.

The Pacific Northwest Region has largely concentrated on developing plant association classifications for National Forests. Many classifications have been completed but several forests remain to be completed. The Region has gaps in classifications for non-National Forest lands.

WHAT ARE MAJOR CLASSIFICATION NEEDS?

Most Regions have ongoing programs in riparian classification. All Regions have done little in classification of alpine lands and the numerous non-forested subalpine habitats. However, the overall major needs seem to be classification of pinyon-juniper and shrublands in general.

The habitat type concept has experienced greater acceptance by managers of forest land than by managers of range lands. The reason for this probably is that we had no ecological classification system for forest lands, but the range site system (Dyksterhuis 1949), developed before the habitat type system, was available for range managers and was accepted and used. The range site system is an ecological classification based on climax vegetation and other factors. Both Daubenmire (1984) and Hironaka (1986) have written papers on the subject.

In my discussions of classification of range lands with Min Hironaka, Ed Tisdale, and Al Winward, they all agree that classifications by range sites could be incorporated into habitat types, perhaps as subtypes. They point out that classifications by range sites, habitat types, and existing vegetation are needed in range management, and incorporation of range sites into habitat types would provide several advantages.

Some of the Regional Ecologists voiced disappointment that the Forest Service Research Stations have been bowing out of the classification program. Some Stations have scientists engaged in classification, but their work usually is financed by National Forest Administration. In my experience, most classification programs are a mix of research and development. I believe they are best conducted as cooperative programs between the Stations and Regions.

My interest in research natural areas leads me to a comment on the value of habitat types to the natural area selection process. Habitat types have proved invaluable to the research natural area program in selecting areas to include the diversity of vegetation. However, classification by habitat types has not been very helpful in preserving very rare plant associations because classifications usually do not include the rare associations. There are exceptions. For example, Bob Steele and Charlie Johnson usually include mention in their classifications of the rare and incidental types they have encountered even though they may not have sampled them. I would encourage all developers of classifications to do this. The importance of preserving natural diversity in all its forms has not really seeped into the consciousness of a great number of Federal land managers.

CONCLUSIONS AND SUMMARY

The habitat type concept of land classification has experienced periods of development, extension, and acceptance. I find it convenient to break the time into three periods:

Through 1970--This was the period of development of the concept by the Daubenmires. Their classifications were examined, tested, and accepted by scientists and land managers, especially in its area of development. It was a period of training ecologists in the concept, especially by Daubenmire at Washington State University and Poulton at Oregon State University. Their students were critically important to the extension and acceptance of the habitat type concept.

1971 Through 1980--This was a period of extension of the classification concept by the Forest Service through major in-service programs, especially in the Northern, Intermountain, and Pacific Northwest Regions. Extension was also by contracts, mainly with university ecologists for classifications, usually for National Forest areas, especially in the Rocky Mountain Region. University and Forest Service Research Station ecologists were active, also, in developing classifications for other specific lands. It was a period of extension, and evolution of methodology to develop and improve classifications.

1981 Through 1987--This period was marked by payoffs of extension efforts begun in the previous period and by a wave of increased classification efforts, especially in the Rocky Mountain, Southwest, and Pacific Northwest Regions.

Classification by habitat types has been developed for much of the forest land of the western United States. The habitat type concept has been much less accepted among rangeland managers, possibly because the range site system of classification has been widely developed and accepted.

As might be expected, classifications by contract for smaller areas of land require more correlation of classifications than large in-service programs covering large areas. Correlation of classifications is needed in all Regions--in some much more than others.

Classifications have varied in their inclusion of soils, landforms, and seral communities within habitat types and their successional pathways, and management implications. In general, classifications developing only habitat types require follow-up to classify seral communities within habitat types, and to determine their successional pathways and management implications. Arno (1982) has written an account of the methodology involved. The trend in recent classification programs in eastern Montana, and the Southwest and Pacific Southwest Regions, has been multifactor classifications. Zone ecologists under the leadership of Fred Hall in the Pacific Northwest Region have continued their multifactor classifications.

Development of habitat type classifications has been a great help in research natural area programs in selecting areas to include the range of ecosystem diversity. However, classifications have not been as helpful in preserving rare habitats because these are most often not included in classifications.

Classification of land by habitat types has proved to be very helpful in land management. Land managers, especially foresters, have generally accepted habitat types as an important tool in management. On-the-ground use of habitat types as an aid in prescribing management practices is common in some Regions but not common in others.

Although many gaps in developing classifications for land situations remain, progress is very encouraging. Some of the major jobs ahead are:

- Completing gaps in classifications.
- Correlating existing classifications.
- Developing classifications for seral communities within habitat types and determining their successional pathways and management implications.
- Refining classifications after gaining experience in their use.
- Mapping of habitat types.
- Developing better productivity estimates of each habitat type.
- Fitting classifications by habitat types into an overall land classification framework.

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BASIC CONCEPTS OF USING VEGETATION TO BUILD A SITE CLASSIFICATION SYSTEM

Robert D. Pfister

ABSTRACT: Three kinds of concepts are reviewed. Basic ecological concepts are critical to understanding vegetation-site interrelationships. Classification concepts are helpful to make meaningful comparisons among different classification approaches and uses. Application concepts are necessary to ensure optimum use of the ecological classifications in natural resource management.

INTRODUCTION

This symposium is possible only because vegetation based site systems are now available for much of the land area in the western United States and because they have been widely employed in various fields of natural resource management.

The basic ecological concepts or ideas underlying the systems are found in many textbooks, classification monographs, and numerous publications. The basic concepts of classification, per se, are less readily available, while the basic concepts of applying the classification systems to natural resource management are still evolving.

Managers can, and often do, use classifications as a "cook-book" approach, without fully understanding the basic concepts. However, a true understanding of a few fundamental concepts allows the user to go beyond the mechanical aspects and enjoy some true understanding of ecosystems.

Concepts are ideas, as distinguished from perceptions. We each see things from one point of view--our own! This paper is my perception, but I am searching for the perceptions that I believe are held in common by a large number of people here. Different perceptions of the same object or subject lead to vigorous debate that can be productive, destructive, or simply noisy. My goal is to document the common foundation, the common denominator, that has led to widespread acceptance and application of vegetation-based site classification in this part of the world. This common perception represents the basic concepts.

To achieve this goal, I will need to condense and simplify--perhaps to the chagrin of some intellectual purists. However, simplification is essential for communication--and communication is essential for transfer of knowledge. The fact that large numbers of natural resource specialists are successfully applying ecological classifications illustrates the achievement of a common level of understanding and communication.

One definition describes science as the process of developing knowledge through four basic steps: (1) observation, (2) description, (3) classification and (4) abstraction. Ben Stout, the former Dean of the School of Forestry at the University of Montana, used to "twist my tail" continuously in reference to the status of habitat type classification. He pointed out that we had completed step three for some areas, but when were we going to do step four? Naturally this challenge has been a "burr under my saddle," leading me to look beyond classification to the final step.

I went to dictionaries for a better understanding of *abstraction* and found many meanings:

1. To separate or extract--to consider separately.
2. Mathematics--a group without regard to character of elements.
3. Expressing a property apart from the real object or thing.
4. Theoretical--apart from practical or actual conditions--the realm of pure science as opposed to applied science.
5. Not easily understood--abstruse.
6. To summarize or condense.

I also stumbled across the term *abstracted*, which means lost in thought and unaware of physical surroundings and realities. You have all met abstracted people--one synonym is "absent-minded". The charitable thing to do is to assume that all those "absent-minded" professors that you put up with were actually totally involved in the final step of science--abstraction!

So now I invite you to take a little trip with me into the never-never land of abstraction, forgetting where we are, who we are, and who is sitting beside us. Let us put on our thinking caps and spend 20 minutes on a couple of questions. What is all this classification stuff really about? Where are these ecologists coming from? My hope is that several of you will be able to say "Aha!" "Something clicks!" or "Now I understand!".

Since the focus of this symposium is on applications to natural resource management, I will not

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concentrate on indepth discussion of any theoretical aspects. Rather, I will attempt to:

1. Separate and review the basic ideas embodied in vegetation-based site classification.
2. Link these ideas for understanding of theoretical aspects (with some real examples).
3. Summarize or condense these basic concepts for general understanding at a common level. In other words, to provide a concentrated essence of a larger whole.

The subject matter of this symposium spans three major groups of professionals:

1. The developers--a few (10's of people) ecological specialists wrestling with theory and data to produce a taxonomy of natural vegetation types as integrated expressions of ecosystem diversity.
2. The application specialists--the several (10's to 100's of people) natural resource specialists involved with analyzing, interpreting and reporting natural resource information in relation to the classification system.
3. The users--the many (100's to 1000's of people) regularly identifying and mapping vegetation types and using natural resource knowledge related to the types.

All of the above will make better use of the powerful tool of classification if they share a common understanding of the basic concepts. Herein lies the challenge of making the complex appear simple --the abstraction of the simple elegance of using vegetation types as an integrated expression of the physical environment.

Through experience, I have learned that it is easier to convey the basic concepts to lay people than to many professionals. This can be described as resistance to learning, an acquired characteristic of our society and even of some of our educational approaches. An open mind is a prerequisite for consideration of new ideas before they are weighed against existing individual perception. My point is--take a trial ride with my perception --weigh it against your own--if we agree, we have achieved a common concept--a shared idea. If we disagree, we have food for more thought and discussion.

Conveying concepts with words alone is difficult, especially with the English language (illustrated by my search for definitions of abstraction). Mathematicians resort to equations or functional expressions. I have found pictures or figures extremely useful in illustrating concepts and will use those that have been most helpful to my own understanding and teaching.

BASIC ECOLOGICAL CONCEPTS

1. The Ecosystem Concept (Tansley 1935)--A broad perspective emphasizing that all organisms and their environment are inter-related. This may be portrayed as a multi-dimensional web or as a diagram of structural components (fig. 1). Synonyms are shown to help avoid confusion in terminology.

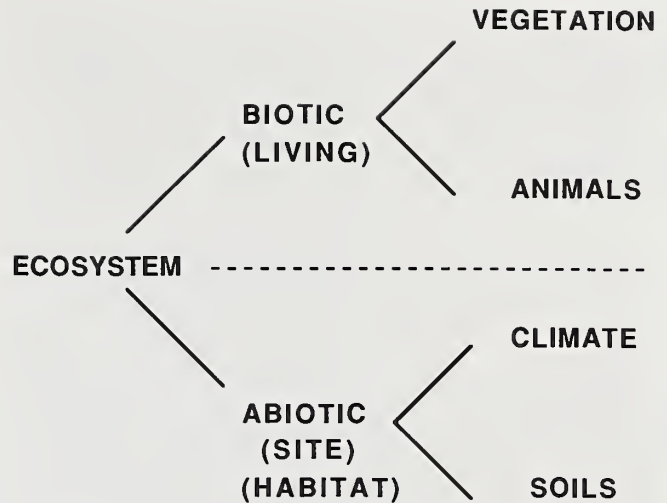


Figure 1--A hierarchical illustration of the components of an ecosystem (with synonymy).

From left to right, we separate the biotic (living) components from the abiotic (nonliving) that we call the *physical environment*, or *habitat*, or *site*. The next subdivision (four major components) is a focal point for vegetation-based site classification. This is where we interpret vegetation as a reflection of the other three components.

2. Vegetation is an Integrated Expression of Physical Environment (and Animals and Time and Treatments)--(Daubenmire 1952, 1968).

Vegetation = f (Flora, Climate, Topography, Soils, Animals, Time, and Treatments)

The occurrence of plants in a given place is controlled by available species, competition over time, and all factors of the ecosystem. In order to use vegetation as a land classification system, one must hold certain factors constant to study relations among the others. This has been done effectively by selecting sample stands for study that:

- a. are within a specific region (control of Flora),
- b. are not strongly influenced by grazing (control of Animal),
- c. are natural stands (control of Treatment),
- d. have reached a degree of stability (control of Time).

These are the stands that reflect the combined effects of Climate, Topography (microclimate), and Soils.

3. The Natural Climax Community Best Reflects Environmental Potentials (Daubenmire 1981)--The concept of climax as a stable, self-regenerating permanent entity is a subject of ecological debate. Nevertheless, acceptance of a degree of stability reached in the process of secondary succession is common to most vegetation-based site classifications. The terms "potential natural vegetation,"

"stable, late-seral," "near-climax" or a special definition of "community type" are often used where "climax" is difficult to determine or to defend with concrete examples. Although complex and difficult to define precisely, the concept is essential. Difficulties in definition need not be a roadblock for developing practical, operational vegetation-based site classification systems.

4. The Time Frame for Climax is Relatively Short.--Most operational, vegetation-based site classifications are based on interpretation of climax as a late, stable stage of secondary succession. In forest conditions, this stage is reached as seral trees are replaced by ones with greater understory tolerance--a period of 200-500 years in the Rocky Mountains. Trends in tree competition are readily interpretable from stand table data, and undergrowth species composition stabilizes relatively early under the forest canopy. This leads to a fair degree of confidence in interpreting the potential climax composition and defining types. Interpretation of climax is related to current climatic and site conditions rather than speculation on unpredictable long-term changes in either climate or site (due to primary succession).

5. The Association is the Basic Unit of Vegetation Classification.--The plant association is the abstract, taxonomic unit defined by the ecologist's intuition. It is based on grouping of similar late-successional stands by two major criteria:

- a. stands having similar vegetation composition, as determined by synthesis table examination, evaluation of differential or character species, numerical analyses, interaction with other ecologists, and accumulated autecological and synecological understanding of the study area and species, and
- b. observation of commonly occurring ecotones or transitions between types in the field.

The term *association* is generally accepted and widely used as having some degree of floristic and physiognomic uniformity, due to uniform *habitat* conditions. Some of us simply define *association* as *climax plant community type*, recognizing that the degree of uniformity and the number of types (lumpers vs. splitters) is a matter of judgment for each individual syntaxonomist, relative to the diversity of each geographic area.

6. The Habitat Type is the Basic Unit of Site Classification (Daubenmire 1952)--Once the associations are defined, a key can be constructed to identify the potential climax type for most successional plant communities. This enables users to recognize all land areas capable of supporting a specific association. This is the strength of the system that has led to widespread application for natural resource management. Sites (*habitat types*) can be identified for individual resource inventory points, and maps can be constructed by locating the ecotones that represent transition from one *habitat type* to another.

7. Vegetation Varies With Time and Space--This is one of the oldest and most elemental concepts, but

STAGES OF SECONDARY SUCCESSION

CLIMAX & NEAR CLIMAX	ASSOC. A	(DATA	BASE	FOR	HABITAT	TYPES)	ASSOC. G
LATE SERAL							
MID-SERAL							
EARLY SERAL							
PIONEER							
	H.T. A	H.T. B	H.T. C	H.T. D	H.T. E	H.T. F	H.T. G
	(warm, dry)						(cool, moist)

Figure 2--Vegetation variation in time and space illustrating association and habitat type concepts.

is still very useful to illustrate the inter-relationships between the association and the *habitat type*. This illustration (fig. 2) is limited to natural vegetation, without consideration of grazing, frequent fire or management treatments (which would require additional dimensions). If we represent all natural vegetation in two dimensions, one for successional stages (time) and the other for a generalized environmental gradient (space), we can illustrate the process of developing a *habitat type* taxonomy:

- a. Sampling the oldest (late successional) stands available on the landscape, which may represent late-seral, near-climax, or occasionally, even climax conditions.
- b. Grouping of similar stands (projected toward climax) defines the associations.
- c. Arranging them from left to right displays their relative positions along a generalized environmental gradient.
- d. Constructing a key that will work with most successional stages extends the vertical line to define the columns, and thereby the *habitat types*.

The upper row represents the defined associations. The columns include all successional stages leading toward a specific association, and represent the subdivisions of the physical environment we call *habitat types*.

Thus, we can visualize the *habitat type* as representing all the land area capable of supporting, at climax, a specific association. (The figure also illustrates the lack of data for defining earlier successional stages; the dotted lines are very general approximations of successional stages.)

8. Nomenclature Can Be a Source of Confusion.--The first problem we have created and continue to promulgate is the fact that we use the same name for two different things--the association and the *habitat type*. This is defensible because of the

intricate linkage between the two, but it is usually confusing to the student. It may be helpful to explain that there are two classifications in one. The first, the vegetation type (association), provides the basis for the second, the site classification (habitat type). When we say *Pseudotsuga/Physocarpus*, we haven't communicated anything until we add the noun of association or habitat type!

Another apparent problem is the desire of some ecologists to make the name more descriptive by adding multiple species. This will add specificity, but it also adds the burden of length for the user who has to write it down or say it regularly.

Another problem for some people is that short-hand jargon or numbers are often used for types for ease of communication or analysis--sometimes to the point that "outsiders" feel they are hearing a foreign language. While these extremes may be frustrating, they are really matters of communication protocol and should have little bearing on the basic concepts of classification or application.

9. Principle of Competitive Exclusion- Rule of Monospecific Dominance (Daubenmire and Daubenmire 1968)--The principle of one species eliminating another species completely is rare in plant communities. Rather, a trend toward one species gaining dominance over another is more realistic. The nomenclature of associations suggests a single-tree species climax, but minor climax or even co-climax status is maintained by a second species in several defined associations. Crawford and Johnson (1985) document dominance of a "short-tree", *Taxus brevifolia* within part of what other authors describe as the *Abies grandis* series. This may be a point of debate regarding the exact definition of climax composition, but has little effect on the application of habitat types as a site classification system.

10. Hierarchies--Convenience or Dogma?--The size of an association is left to the judgment of the individual ecologist developing the taxonomy. These ecologists refer to each other as "lumpers" or "splitters!" Associations are commonly grouped (based on the same upper layer of climax dominant species) and termed series. Associations can also be subdivided into phases to reflect minor differences. Crawford and Johnson (1985) provide a good review of hierarchies and terminology and suggest tightening up the specificity of both.

Although the ecologist using a specific hierarchy may feel it is the most logical and best way to split or group types, we have observed other specialists regrouping our types in different combinations more defensible for their specific needs or objectives. This represents another situation where the grouping/splitting conventions should not be considered critical to the basic classification concepts. Unless used as dogma, it also should not be critical for application concepts.

11. The Principle of Factor Interaction or Compensating Factors--The fact that similar vegetation can occur on a variable range of interacting site

factors illustrates interaction or compensation of one factor for another. This principle is critical for meaningful communication among soil scientists and plant ecologists. (It also would provide a good focal point for the current Range Site vs. Habitat Type debates.) Acceptance of the principle allows one to infer or hypothesize the influence of major factors determining the distribution of habitat types on the landscape.

12. The Polyclimax Concept (Tansley 1935)--This links the concept of relatively short-term climax and the principle of factor compensation in the definition of three primary climaxes--climatic, topographic and edaphic. Most associations can occur as a representation of macroclimate on gentle topography and "normal" soils, thereby reflecting a climatic zone. The fact that the same association can occur both as a climatic climax and as an edaphic or topographic climax in another macro-climatic zone illustrates factor compensation. Some associations are even restricted to unique topographic (micro-climatic) or edaphic situations. For example, the *Pinus contorta/Purshia tridentata* habitat type in the vicinity of West Yellowstone is an example of a unique topo-edaphic climax potential (Pfister and others 1977).

The primary climax potentials (associations) represent the complete upper row in figure 2 and all the land area included in a study area. As such, they form the foundation of the habitat type classification. However, other stable plant communities can be found if the factors of prolonged heavy grazing or regular, frequent fires or other regular additional modifications of the system are added. These are termed secondary climaxes or disclimaxes and would need to be shown as a third dimension in figure 2.

13. Succession--Primary and Secondary--We all have been schooled in the basics of primary plant succession--with pioneer species changing the environment to allow secondary species invasion (generally over a very long time period). We have looked at examples of hydrarch and xerarch succession and must recognize that the slow process of primary succession is continuous, even if we cannot see it and do not measure it. Although primary succession cannot be ignored, it is not critical to upland site classification and management applications, unless management treatments are severe enough to erode soil or initiate a primary succession.

Our area of immediate concern is really secondary succession--the changes in vegetation in response to common disturbances such as fire, insects, disease, windthrow, logging and other vegetative manipulation treatments. This range of possible treatments means it is necessary to add at least one more dimension to our basic figure 2. One approach is to take a single column (habitat type) out of figure 2 and depict multiple successional pathways leading toward (or away from) climax. These may take the form of triangles, cones, or pyramids, as will be illustrated in later papers in this symposium.

Holding environment constant through the use of habitat types aids in understanding of the time and

landscapes to define areas of relative homogeneity for land use planning.

Habitat types were specified as a part of ECOCLASS (Corliss 1973) in the context of mapping and overlaying of maps to define *Ecological Land Units*. Associations were used as a part of the NATIONAL LAND CLASSIFICATION (Driscoll and others 1984), a component taxonomic system used to apply multiple taxonomies to a point or small unit of land--the dual name being termed an *Ecological Response Unit*. The fact that ECOCLASS was a mixture of taxonomic and regionalization concepts and that the NATIONAL COMPONENT LAND CLASSIFICATION is primarily a taxonomic system illustrates that conceptual problems in the field of land classification are still not operationally resolved (at least not in the literature)!

APPLICATION CONCEPTS

Concepts for application or linking of site classifications to resource management have been evolving for some time and this symposium is the first formal effort to assess how far we have progressed. New ideas and concepts require time and understanding of value to be accepted and implemented.

Daubenmire published the first habitat type classification in 1952. Acceptance and use in forestry research and management during the 1960's led to commitment of research and management dollars to finance expansion and application in the 1970's. The steps or concepts involved in developing an operational system were and remain:

1. Decision About the Kind of System--Land management and research organizations need to decide what kind of ecological classification system is most appropriate (coordination of research and management on this decision is vital).

2. Planning, Finances, and Personnel--Someone must develop a plan, provide or find the financing, and obtain qualified personnel to complete the task.

3. Developing the Taxonomy--An effective vegetation-based site classification requires quality field sampling, appropriate analyses, ecological intuition, and documentation (Pfister and Arno 1980).

4. Training the Users and Application Specialists--Training is crucial and includes understanding of concepts, indicator species recognition, proper use of keys, mapping techniques, and proper interpretation of available management implications.

5. Developing Applications for Natural Resource Management--Applications require development of the relationships between the ecological classification and ecological knowledge relative to appropriate natural resource concerns. This can be done in several ways:

- a. By ecologists, from supplementary data and observations.
- b. By research specialists who stratify their

data, analyze, and report results in relation to habitat types.

- c. By management specialists, summing up their own data, observations, and experience to develop their own local (usually informal and unpublished) guidelines.

- d. By teams of ecologists, resource scientists, and management specialists, pooling their combined knowledge and intuition for a synergistic, documented contribution to knowledge.

- e. By symposiums such as this one!

Each of the approaches has some problems. Many ecologists do not have a strong background in the natural resource areas where interpretations are needed. Many research specialists do not have enough ecological background to make full use of the classification. Management specialists may solve their current, local problems, but there is no mechanism to capture the knowledge for use in other areas.

Team efforts offer the most promise for solid, documented applications. However, team efforts require cooperation, coordination, commitment, and support of upper level management. If formal team efforts are not possible, it behooves professionals to find a way to work cooperatively with other professionals for specific areas of concern.

Symposiums are an effective way to provide a documented update on status of knowledge--this symposium goes a critical next step by addressing the question--"Where do we go from here?"

OTHER CONFLICTS AND RESOLUTION

I would be remiss if I did not mention some concepts that have received a great deal of attention. The ecologists developing the classifications have discussed these in greater detail. Suffice it to say that:

--Acceptance of a continuum philosophy does not preclude one from developing a useful and practical vegetation-based site classification.

--Continuum-based methodology, such as indirect ordination, can provide useful insights into species-site and type-site relationships.

--Direct ordination of species and communities against individual factors is a possible alternative analytical and application approach. However, it has not been as popular for resource application as types that the manager can see, identify, and map in the field.

--Direct ordination of habitat type distribution against elevation and aspect has proved to be a very useful aid to habitat type mapping.

--Numerous mathematical computer assisted analysis techniques are available to make the job of analysis easier if the ecologist maintains control of the classification process.

The foolproof automatic classification that fits

the data, the landscape, and the intelligence of the ecologist who has field familiarity with the data is not yet available, although many have been fooled! Many continue to search for the ultimate in artificial intelligence--which should be considered as an aid to natural intelligence--not as a replacement for it.

CONCLUSION

My goal has been to deal with the abstract--the concepts and ideas basic to using vegetation for land classification purposes. I hope that it did not fit that definition of making it more abstruse or difficult to understand. Rather, I hope that the abstraction represents the following dictionary definition:

Abstract--noun--*American Heritage Dictionary* (Morris 1979):

1. A statement summarizing the important point of a text.
2. The concentrated essence of the larger whole.

If all that failed, then learn a few species and try it yourself--you will like it! Identify a point. Better yet, map a small area and find out how the classification fits the stand or landscape you are working with. Mapping is one of the most rewarding experiences of using habitat types. If you haven't mapped an area, even just 10 to 40 acres, you have really missed something. Use of the classification system in the field is one of the best ways to understand the concepts.

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PRIMARY SUCCESSIONAL THEORIES

M. Hironaka

ABSTRACT: The polyclimax theory is not an alternative to the monoclimax theory. The polyclimax theory deals with primary successional communities in the present-day timeframe. The monoclimax theory projects primary succession into the future until all the primary communities under the influence of the same climate converge and terminate in a single community; the climatic climax. The monoclimax theory, the polyclimatic climax theory, and the no-endpoint theory of primary succession all deal with projection of primary succession beyond present time. With the no-endpoint theory, there is no terminal community because primary succession never ends. The monoclimax theory claims there is one--the climatic climax. The polyclimatic climax theory claims there are several terminal communities, because of terminal soil differences.

INTRODUCTION

Generally, one does not associate primary succession with habitat type (Daubenmire 1952) or range site (Dyksterhuis 1949) classification, but there is a close relationship. Because there are conflicting and inconsistent theories that pertain to primary succession, it is important that we understand how they differ.

Although there is much variability in what is included in a "homogeneous unit," the plant association (American interpretation--see Daubenmire 1968) is the basic unit of classification of climax vegetation. This unit is the basis for the habitat type. The habitat type is defined as the aggregate areal extent of a plant association that an area supports or is capable of again supporting (Daubenmire 1952). Although not stated in specific terms, the range site classification is also a land classification based on the plant association that is constrained by levels of productivity (Dyksterhuis 1949; Shiftlet 1973). The added constraint of productivity makes the range site a more homogeneous land unit in terms of uniformity in species abundance and soils than the habitat type.

Both classifications are based on climax communities, which are the endpoint communities of secondary succession. The endpoint of secondary succession is primary succession. Thus, the communities that make up a plant association are communities of primary succession.

MONOCLIMAX AND POLYCLIMAX THEORIES

The monoclimax theory (Clements 1916; Oosting 1948) and the polyclimax theory (Daubenmire 1968; Mueller-Dombois and Ellenberg 1974) pertain to primary succession (fig. 1). Although some view the two concepts as mutually exclusive (Mueller-Dombois and Ellenberg 1974), they are not when interpreted in the light of habitat type and range site classification because a different timeframe is involved.

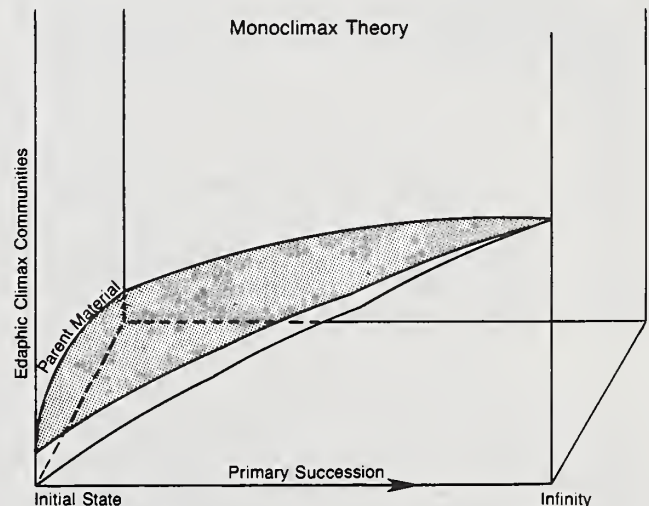


Figure 1--Author's conception of the monoclimax theory. Initial state is the beginning of primary succession on various parent materials. Climate is assumed to remain constant. All seres eventually converge onto a single climax community, the climatic climax.

Although the initial communities of primary succession are numerous and highly different, communities developing under the influence of the same climate eventually converge and become more similar as time passes. The monoclimax theory projects the timeframe of primary succession into the future until succession terminates in a single community; the climatic climax (Clements 1916). On the other hand, the polyclimax theory views

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primary succession through a narrower window of only a few decades and the communities present at the time of viewing are the climax communities that are classified into plant associations. The communities at the time of truncation are often referred to as edaphic, topographic, topo-edaphic, and climatic climaxes. These are the primary successional communities as they exist today, or as they would be if they were not recently disturbed.

The polyclimax theory deals in a different timeframe than the monoclimax theory (fig. 2). The polyclimax communities are primary successional communities of today and not in the distant future as envisioned in the monoclimax theory. It does not preclude the possibility of eventual convergence onto a single climatic climax when sufficient time lapses.

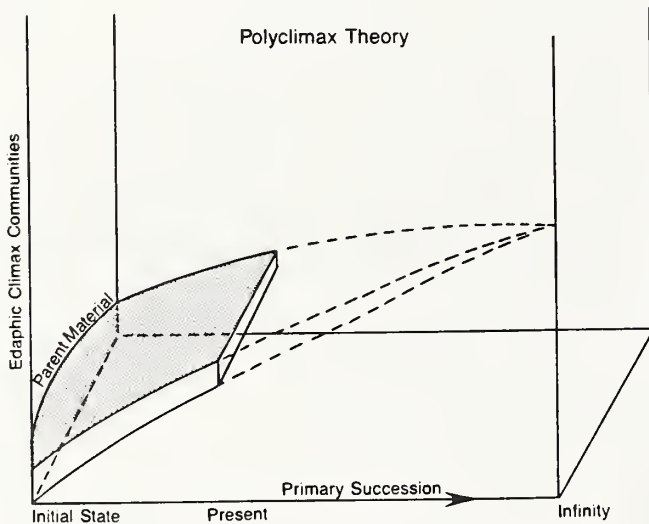


Figure 2--Author's conception of the polyclimax theory. Initial state is the same as for the monoclimax theory. Climate is constant. All seres are terminated as of present time.

If the endpoint of primary succession is thought to be polyclimatic--that is, having more than a single endpoint--the monoclimax and polyclimatic climax theories are conflicting theories (Mueller-Dombois and Ellenberg 1974). Interestingly, the polyclimatic climax theory is based on the premise that soil differences would be responsible for the different climatic climaxes. The use of the term "edaphic climax" for this situation is avoided because its use is already established in the polyclimax sense.

NO-ENDPOINT THEORY

About 10 years ago another primary succession theory was put forth (Pickett 1976). For lack of a name, I prefer to call it the no-endpoint theory (fig. 3). It views primary succession as never ending. Even under the hypothetical condition of constant climate, soil development will continue and the evolution of plants will go on and plant communities will undergo continuous change. The

no-endpoint theory, in my opinion, overcomes the conceptual difficulties inherent in the other theories. It incorporates the dynamic theories of soil development (Jenny 1941; Jenny 1958), soil-vegetation relation (Major 1951) and plant evolution (Stebbins 1974). It has a lot of merit.

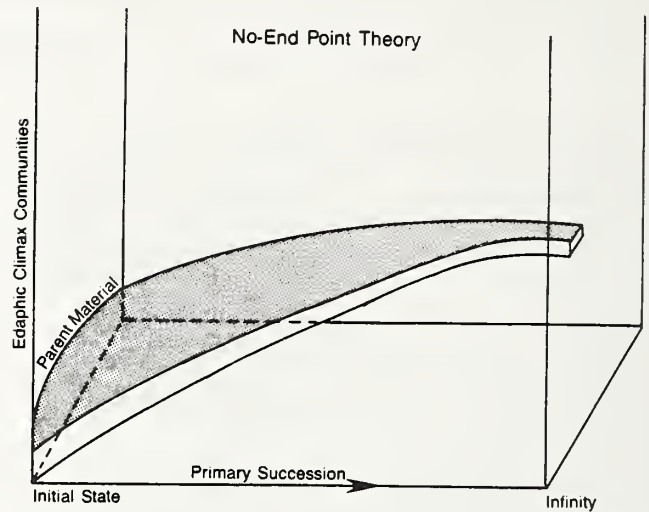


Figure 3--Author's conception of the no-endpoint theory. Initial state is the same as for the monoclimax and polyclimax theories. Climate is constant. Convergence is incomplete and seres do not ever fully converge. Vegetation change continues over time because of plant evolution and soil development.

Acceptance of the no-endpoint theory does away with the confusion associated with the term "climax community." Since primary succession has no endpoint, the term can be only associated with the endpoint of secondary succession. It would still retain its meaning of being the culmination of succession, the endpoint of secondary succession. The term would be universally meaningful, including its usage in context with polyclimax, plant association, habitat type, and range site concepts.

DISCRETE COMMUNITIES VERSUS CONTINUUM

Although it is not often stated, the discrete community versus the continuum controversy is restricted to plant communities (McIntosh 1958; Daubenmire 1966) of primary succession and not communities of secondary succession. The no-endpoint theory reduces confusion by restricting the definition of climax as the endpoint of secondary succession. The endpoint of secondary succession is primary succession. This makes each and every primary successional community a climax community.

For the discrete community concept to be an ecological truth, one is required to accept the idea that contiguous, temporal primary successional communities are abrupt and discrete, even though the successional process, environmental gradients, and time are continuous. This concept is difficult to accept because soil

development is continuous, temporally and spatially (Jenny 1941, 1958), and to expect the plant community to remain virtually unchanged in its entirety for a span of time and then abruptly change into another community is difficult to envision. In addition, plant species tend to become more different through natural selection rather than more similar. This would result in plant communities becoming more heterogeneous and continuous than discrete over time (Whittaker 1975).

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CONSERVATION OF NATURAL DIVERSITY:
THE ROLE OF AN ECOLOGICAL CLASSIFICATION

Patrick S. Bourgeron

ABSTRACT: A goal of The Nature Conservancy is the global preservation of natural diversity. Steps to advance this goal are defined. The Nature Conservancy's efforts towards the regional correlations of local classifications in the western U.S. are presented. A second product of the regional classification will be the improved understanding of diversity patterns, understanding useful in preserve selection and management.

INTRODUCTION

The objectives of an ecological classification must be clearly stated. The tool must match the stated objectives. The purpose of this paper is to summarize The Nature Conservancy's approach to ecological classification that is used in the western U.S. and the potential use of the classification to preserve natural diversity.

GOALS OF THE WESTERN REGIONAL ECOLOGY EFFORT

The Nature Conservancy's mission is the global preservation of natural diversity. As part of a National Task Force, the western regional ecology effort has, among others, two stated objectives:

- (1) To develop an internally consistent ecological classification for the western portion of The Nature Conservancy's global system.
- (2) To apply the above system to the selection and management of ecological systems for conservation in a regional/continental perspective.

NEED FOR CLASSIFICATION

It is appropriate to ask: (1) why do we need a

classification for conservation of natural diversity? (what are the relationships between natural diversity and classification?); (2) why a regional approach? (what are the implications of a regional approach to the conservation of natural diversity?)

Natural (or biological) diversity is generally defined as the diversity of life forms (such as species), their genetic diversity and the ecological functions and processes they perform (Wilcox 1984). Natural diversity is also conveniently organized at different levels (table 1). At each level, the fundamental unit is an element. This definition of natural diversity identifies entities that serve as focal points for conservation, research, and management.

The Nature Conservancy uses a "coarse filter/fine filter" approach to preserving natural diversity (Jenkins 1976). A primary objective is to protect examples of each of the communities (the coarse filter) found in an area. In this way, 85-90 percent of the natural diversity found in the area will be preserved (Jenkins 1976, 1982). In addition, preserving high-quality examples of communities is of importance in itself since these examples demonstrate ecological processes and serve as experimental controls against which other management strategies can be compared (Jenkins 1982). Rare and endangered species are most likely to fall through the cracks of the "coarse filter" (Jenkins 1976). The "fine filter" is aimed at these species that are dealt with on an individual species basis (The Nature Conservancy's Heritage operations manual 1987; see discussion in Jenkins 1976, 1982).

An ecological classification must therefore (1) identify all communities (to preserve the full array of communities), and (2) define the range of each community (to preserve the full array of natural diversity found over the range of each community). When these two criteria are met, this classification provides a good basis for preserving the full array of elements that compose natural diversity over any area. A regional/continental approach to community classification is necessary to identify all communities and define the range of each one. The definition of an optimal strategy for preserving the full array of natural diversity clearly demands a regional/continental approach.

Paper presented at the symposium, Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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In summary, the community concept is central to the global preservation of natural diversity. Landscapes need to be divided into communities that are units that occur repeatedly in time and space. The community is used as a "coarse filter" to preserve groups of species in relatively homogeneous habitats over the landscape. A regional classification is used to generalize knowledge about a few samples located in the region to as many stands in the whole area as possible. The "coarse filter" thus defined enhances our efforts to preserve natural diversity with economy.

Table 1--Organization of natural diversity at different levels. Adapted from Wilcox (1984)

Level of Organization	Component	Element (Example)
Molecular	Genes	Genes for salinity tolerance and resistance to verticillium wilt in the strawberry <u>Fragaria chiloensis</u>
Populational	Populations	Deer herd in George Reserve
Species	Species	Grizzly bear (<u>Ursus arctos</u>)
Ecosystem	Community	<u>Abies lasiocarpa</u> / <u>Vaccinium caespitosum</u>

A STRATEGY

During the process of building a regional classification and using it as the "coarse filter" for the global preservation of natural diversity, the following questions need to be addressed:

- (1) What are the local communities found in a landscape? (This is the classification proper.)
- (2) What is the range of distribution of the above communities? (These are the regional correlations of local classifications leading to the regional/continental classification.)
- (3) What are the relationships of communities to one another, and to the environment, both locally and regionally? (This is the ecological interpretation that gives the classification its predictive power.)
- (4) Is there a relationship between local community diversity and other levels of diversity? (This is the search for the respective role of local and regional

processes and historical events in generating and maintaining local community diversity.)

- (5) To what extent will reduction and alteration of habitats modify patterns of diversity in local communities and over the range of distribution of a given type? (This is the search for an optimal regional/continental protection strategy.)

To answer these questions requires an ecological classification that is internally consistent and that is based on sound ecological principles (Pfister 1986). In the western U.S., The Nature Conservancy uses the plant association concept (Braun-Blanquet 1921, 1964; Daubenmire 1952, 1968, 1970; Daubenmire and Daubenmire 1968; Flahault and Schroter 1910; Pfister and Arno 1980). This approach ensures that the criteria of consistency and ecological soundness are satisfied. It also allows The Nature Conservancy to make use of the large array of data that is available today over the western U.S. The Nature Conservancy's system includes communities that are compositionally and structurally maintained by recurrent natural disturbances, such as fires and grazing by large native ungulates. In the habitat typing system, the term plant association is restricted to climax or potential natural vegetation types (Daubenmire 1968; Pfister and others 1977). In agreement with the original definition of a plant association (Flahault and Schroter 1910), the subclimax and seral communities are recognized using the same criteria as the climax types, but they are called community types to keep The Nature Conservancy's system compatible with the widely used habitat typing terminology.

AN EXAMPLE OF THE REGIONAL APPROACH

To illustrate the steps involved in answering the first three questions, we will take the example of the spruce-fir forests with Vaccinium in the understory and related types. Twenty-five types falling in this complex were found in 32 publications. Their acronyms are:

ABLA/CABI	ABLA-PIEN/VASC
ABLA/LIBO	PIEN-ABLA/PAMY
ABLA/LUHI	PIEN-ABLA/VACA
ABLA/RUPA	PIEN-ABLA/VASC
ABLA/SETR	PIEN/CALE
ABLA/STAM	PIEN/LIBO
ABLA/VACA	PIEN/VACA
ABLA/VAGL	PIEN/VAMY
ABLA/VAME	PIEN/VAMY-POPU
ABLA/VAMY	PIEN/VASC
ABLA/VASC	PIEN/VASC-PODE
ABLA-VASC/LIBO	PIEN-RIMO-PODE-BROM
ABLA-PIEN/VASC	

Each publication provides a local answer to questions 1 and 3. However, without the regional correlations of these types, we do

not know how similar or dissimilar they are. Names alone are of little value at the regional scale, as authors may have different naming conventions, and ecological similarities or dissimilarities are not necessarily apparent from the name. The regional correlations of local types are the means of answering the following questions (Johnston 1983): Are types with identical names the same? Are types with different names separate entities? Is a phase in a local classification a true phase of a type or the expression of a related but distinct type at the limit of its range? How do finalized regional types relate to one another and to the environment?

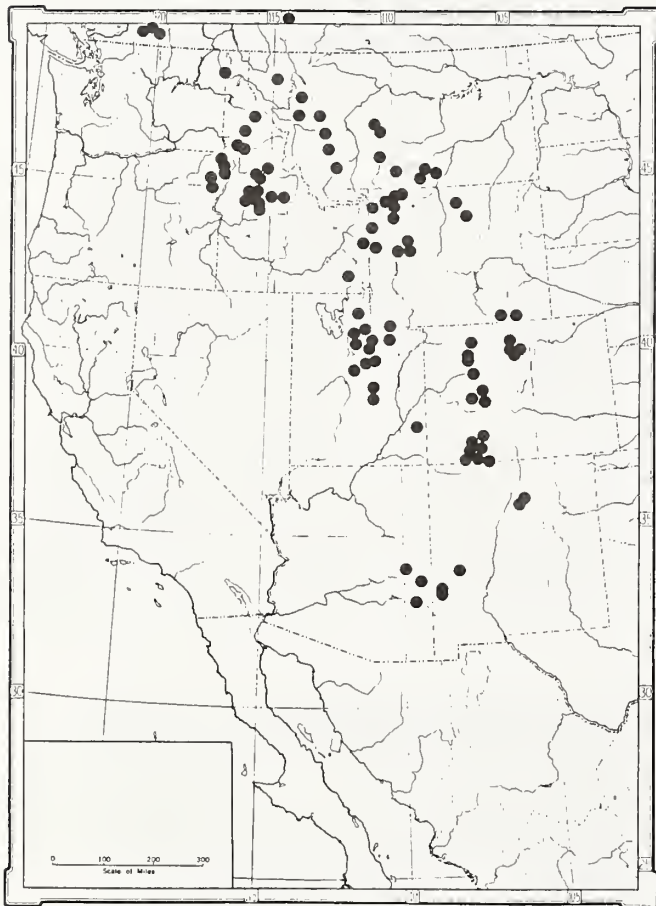


Figure 1--Map of the areas where the study spruce-fir types were sampled.

The regional correlations of the types are based on the summary tables. Work focuses on how local types relate to each other, and whether they should be lumped under the same name. To use published data sets, two criteria had to be met: (1) concepts and methodology used to define the types had to be similar and (2) data had to be expressed in percent cover (most of the publications used this or a cover class) or in a unit easily

converted to percent cover. All but 3 of the 32 publications described "habitat typing" classification.

Ninety-six summary tables, including phases when available, were retrieved. The represented areas ranged from Canada to southern Arizona and New Mexico (fig. 1). Data were lumped at the species level. Nomenclature follows Kartesz and Kartesz (1985). Total number of species and the breakdown by life form are:

Total number of species = 491

Trees = 22
Shrubs = 74
Graminoids = 80
Forbs = 307
Others = 8

On-going analyses include clustering, ordination and analysis of variance. The dendrogram (fig. 2) was obtained with Ward's method variable transformation (Orloci 1967), a polythetic agglomerative technique available through CLUSTAN (Wishart 1978), using squared Euclidian distance (Orloci 1978) on unstandardized data. To fit CLUSTAN's dimension requirements, the data set was reduced to include only the 189 species with cover greater than 3 percent.

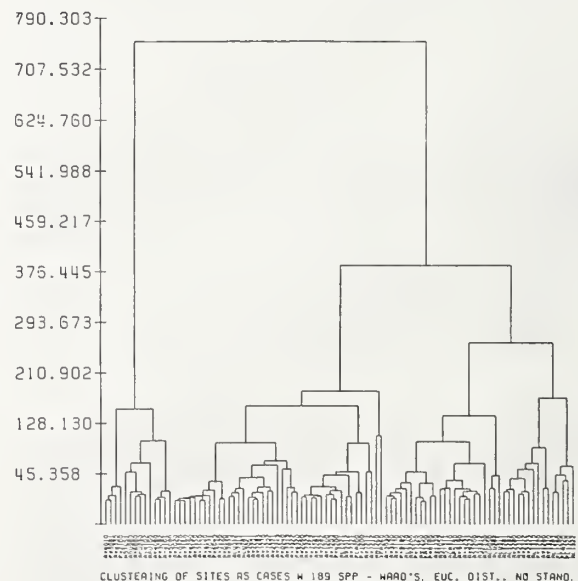


Figure 2--Cluster dendrogram of the summary tables using Ward's method.

Five groups are identified in figure 2. The first break separates types found in Arizona, southern Colorado and New Mexico (group 1) from types found north of southern Colorado Gunnison National Forest (groups 2, 3, 4 and 5), but for two exceptions. These are a southern Arizona type and a central Idaho type that are associated with group 4 and 1 respectively. Group 4 and 5 appear to separate the cool and drier *Abies lasiocarpa* and closely related types (group 5) from the cool but moister (or less summer drought constrained) *Abies lasiocarpa* and closely related types (group 4). Group 3 appears to include types on sites dominated by cold air drainage or accumulation. Group 2 includes all other types.

These results are preliminary and are shown only to illustrate the complexity to be encountered in correlation efforts, including the complexity of possible relationships among types. Enthusiasm for cursory geographical and environmental interpretation of the clusters is tempered by (1) the indication of possible misclassification due to the technique and (2) the fact that phases of the same types are sometimes found in various groups. Further work will include: analysis of the species groups leading to the clusters, the sensitivity of the results to various species reduction and transformation strategies, the use of other techniques, structural and diversity analysis, ordination, and other approaches to clarify the ecology of the associations.

USE OF CLASSIFICATION FOR DIVERSITY PATTERN ANALYSIS

The regional/continental classification will permit the determination of species diversity patterns within small areas (stands) of matched, similar and homogeneous habitat within regions. Using the "coarse filter" approach, most of the natural diversity can be protected over time. However, long term protection requires understanding of the processes that generate and maintain diversity in local communities. Ecologists are beginning to realize that local community diversity reflects the influence of global processes, such as dispersal, species production and unique and historical circumstances, as well as local factors, such as competition, predation and grazing (Ricklefs 1987). Determining the relative role of local and regional processes that generate and maintain natural diversity is central to its long-term maintenance.

If local conditions determine local community diversity, variation in diversity at higher levels should have little influence on local community diversity (Cornell 1985a,b; Ricklefs 1987; Terborgh and Faaborg 1985). This interest in diversity at different levels relates directly to question 4: Is there a

relation between local community diversity and other levels of diversity? The regional approach to classification provides the data to test the relation between different levels of diversity in habitats that are considered to be either the same or similar.

As an example of such a use of the ecological classification, the number of shrub species found on the average in a stand of a given plant association (of the spruce-fir complex) is plotted against the total number of species that can be found in the same plant association over a large surrounding area such as a national forest (fig. 3). The significant correlations between the two levels indicate that shrub diversity depends on the overall number of shrub species that can survive that kind of environment. Therefore the number of shrub species found on the average on a given site is sensitive to processes such as geographic dispersal and historical accumulation of shrub species that can be found in the given type of habitat over a given area. To this extent, any reduction in the number of shrub species that can be found in the types considered over the area will initiate a decline in local shrub diversity in the same types, from which there is no recovery. This result implies that preservation of the maximum number of shrub species that can survive in the given environment over the area considered is necessary to preserve shrub diversity in any occurrence of the types considered. At present, we are doing the same analysis at other levels of ecological organization.

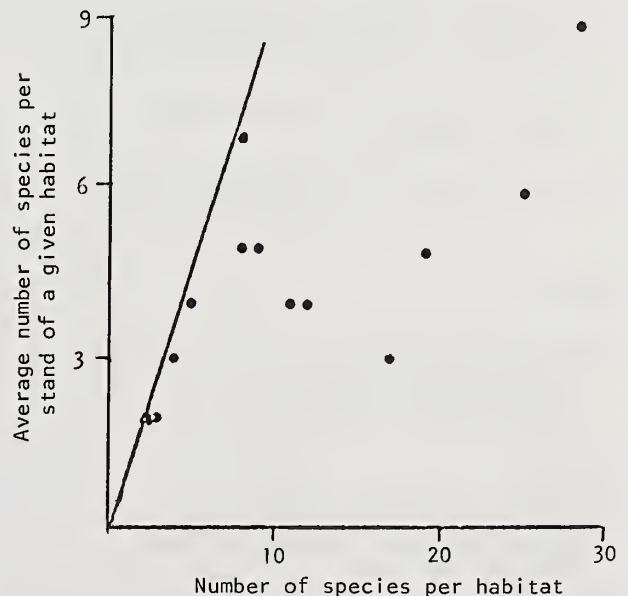


Figure 3--Relationship between the average number of shrub species at one site and the total number of shrub species found in the same habitat over a large area.

CONCLUSIONS

To achieve our goal of conserving natural diversity, we must have a sound ecological classification as a tool. This classification needs to be standardized to compare patterns over landscapes, over whole regions, or even over whole continents. Local classifications must be correlated regionally and/or at the continental scale. The use of a standardized classification system over large areas permits the kind of regional correlations that The Nature Conservancy is doing at present in the western U.S. The final product will be a regional classification.

With such regional/continental classifications, ecosystem patterns, structure and dynamics, and diversity patterns can be studied at all the proper spatial and temporal scales that influence the characteristics of ecosystems. Optimal strategies for the global preservation of natural diversity (Jenkins 1976, 1982) based on the "coarse filter" approach can then be defined.

The Nature Conservancy's efforts toward the global preservation of natural diversity include the following steps, that are part of its long-established Natural Heritage programs (see Jenkins 1982), and its preserve selection and design and stewardship efforts:

- (1) A regional classification of all ecological systems.
- (2) A basic model of diversity patterns in all ecosystems.
- (3) Detailed models of relations of diversity patterns at different levels of ecological organization.
- (4) An integrated management system of the above information.
- (5) Guidelines on conserving and managing units of the classification.

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EDUCATION AND TRAINING FOR PERSONNEL WORKING

WITH VEGETATION-BASED LAND CLASSIFICATIONS

Frederic D. Johnson

ABSTRACT: Results of a poll sent to 80 forest agency silviculturists in the far-western United States indicate a lack of confidence in the accuracy of field crews who are applying vegetation-based land classifications. Almost three-fourths of respondents believe training is inadequate. Most data generated by field crews goes into a permanent data base. New professionals and superiors are judged weak in appreciation of the complexities of such classifications. Longer and better training programs are an indicated need. A poll of 9 of 11 far-western accredited forestry schools reveals that undergraduate forestry students apparently need more time in field practice of vegetation classification, more exposure to concepts critical to understanding these classifications, and better understanding of plant identification.

INTRODUCTION

When asked to present a paper on the education and training of practitioners of the exotic art of classifying land by plant communities, I accepted readily. I've been teaching field habitat typing since 1956—to undergraduates in field ecology at summer camp for over 25 years, to graduate students in a fall course for over 20 years, and to practicing professionals in 15 week-long short courses taught over the past 10 years. Although I definitely had some ideas on the subject, I soon realized that my experience would translate to anecdotal material. I had no real data.

I had plenty of horror stories—especially from graduate students and professionals, many who volunteered "I've been doing this all wrong"—"for all last summer", or "a couple of years", or "for several years". Stories of misidentification—such as the crew that mistook *Erythronium grandiflorum* for *Clintonia uniflora*—which in these parts is about equivalent to calling a Douglas-fir a whitebark pine. The whole summer's work for that crew had to be repeated the next season. I heard of a crew working in clearcuts who identified *Ribes viscosissimum* as *Physocarpus malvaceus*, and thus, since Douglas-fir had been planted, typed a western hemlock habitat as *Pseudotsuga/Physocarpus*. Just a couple of months ago a non-forestry graduate student on a 3-man field crew came in and indicated he felt that their habitat typing was not being done properly (he put it more succinctly!). As I questioned him it was soon evident he was right. Then he asked another question. "How do you tell grand fir from subalpine fir?" "You mean your crew-boss can't help you?", I asked. "No, he asked me to find out." I hear repeatedly of field crews standing midst a brush field, or in a newly burned clearcut trying to determine forest habitat type. Anyhow, lots of feedback over the years.

But no *real* data! So I sent out 91 questionnaires. One set of questions went to each of the 11 accredited forestry schools in the far west—(NAU, UA, UC-B, HSU, CSU, UI, UM, OSU, USU, WSU, and UW). A different questionnaire was sent to 80 district silviculturists for USDA Forest Service, Bureau of Land Management, and Idaho Department of Lands. Locations were determined on a semi-random selection from directories. There was a slightly heavier weighting to Idaho and Montana since they have been using forest habitat typing for the longest period. Agencies in California were not polled, since their classification is just beginning to be used. But, agencies in all ten of the remaining far-western states were polled.

AGENCY QUESTIONNAIRE

Of the 80 sent to silviculturists, 71 (89%) were returned. (Could the high return rate indicate high interest?) Of those returned, 83 percent (59/80) had a forest habitat type or forest association classification for their area. For the 17 percent that had no classification available, 60 percent expected one in under 2 years.

Asked to evaluate the local forest habitat or plant association classification: 80 percent checked "very useful", while only 5 percent checked "of little value". Another 5 percent indicated that local manuals had erroneous information or that there was a need for updating the manual or that there were poor or misleading keys.

Comments: "The best working tool for foresters I've used in 25 years".

"Would be better if more professionals understood it".

"Needs better management implications".

"Lacks usable keys".

"Needs better pictures".

After this general question, there were three parts, one for non-professional and seasonal personnel, one for contractors and one for professionals.

Non-professional and Seasonal Personnel

Two-thirds (39/59) of the professional silviculturists replying would like to screen applicants for seasonal work for prior experience or training in forest habitat type or association work. Less than half (28/59) indicated that this was possible. One respondent presented an interesting contrast: "Could applicants be screened?" — "YES." "Do you prefer to screen them?" — "NO".

Comments: "We'd like to screen applicants but haven't had that luxury yet."

"Hiring practices won't allow screening."

"We can do limited screening only if we have sufficient applicants."

Paper presented at the Symposium on Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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Training is a matter of considerable interest and the results of the related series of questions was variable. The question asked: **How much field training do new personnel for which you are responsible receive before using the classification?** The results:

<u>Response</u>	<u>Percent/Number</u>
No training at all	12% (7/59)
3 - 8 hours	47% (28/59)
12 - 16 hours	8% (5/59)
40 hours (5 days)	10% (6/59)
Indefinite or variable	15% (9/59)
Blank	7% (4/59)

From these data, three-fifths of non-professional and seasonal personnel receive one day or less of training in identification of forest habitat types or associations.

Whatever the training period, 71 percent (42/59) indicated that data taken by seasonals or non-professionals went into a permanent data base! I went back through the questionnaires to develop this interesting point: of the 59 percent of seasonals or non-professionals with from 0 to 8 hours training in vegetation classification, 91% indicated the data went to a permanent data base. It seems the less the training, the more likely was the data to get to a permanent data base!

The responses to the question, **Who conducts the training?**, were so variable that they were difficult to group. Seasonals with experience (10%) were involved in training other seasonals. Crew supervisors were involved in 15 percent of the training, but crew bosses are often seasonals. "Experts", such as zone ecologists, authors of classification manuals, instructors in university shortcourses or ecologists on contract accounted for 15 percent of training programs. Many answers (29%) were of dubious value with answers like "USFS" or "BLM" personnel. The remainder were too variable to classify.

Are the training programs (for seasonals and non-professionals) adequate? No: 72 percent (41/57), Yes: 28 percent (14/57), blank—2 responses.

How can training programs be improved? "More time with experts," was the reply for almost half (46% - 27/59). This figure combines a variety of replies, such as: "More time with zone ecologist", "several days to a week with experts", "take university short-course", "everyone should spend a week with outside experts", "... would like to send more workers to the 40-hour course". More time for training was the reply by 20% (12/59). By contrast, one remark: "Three hours of training produces an adequate job." Some indicated better preparation by instructors (15% - 9/59).

Suggestions for improvement brought some interesting comments. Several indicated that their professional personnel needed more preparation in college, stressing concepts, classification systems and plant identification. And, along this line, another group (24%) indicated a need for better understanding of concepts and "theories" on which vegetation-based classifications are founded.

A pertinent general comment fits well here: "My superiors have no idea what a habitat type is, how hard they are to determine, or how to apply them!" From my experience in conducting professional-level habitat type short courses; it is very rare that upper echelon administrators attend, and if they do, it's for a few hours of field work during a week long course. Perhaps this is part of the problem with inaccurate data reaching permanent data banks.

Contractors

Another section of the agency questionnaire dealt with contractors. The lead question was **Are contractors who are required to provide association/habitat type/community type judgments adequately trained and qualified for classification work?** The answers: No:

44 percent (26/59), Yes: 19 percent (11/59), possibly or maybe: 2 percent (7/59), unintelligible or blank: 25 percent. There were only a few comments from those who did not reply; however, three respondents indicated that they don't have contractors do vegetation classification due to lack of training.

Who Trains Contractors? If I have interpreted a variety of responses correctly, then contractors train themselves. Only 3 of 59 respondents indicated they trained contractors. There was a general tone from comments that contractor work on vegetation typing is suspect. Which brings us to a final statistic on the apparently self-trained, ill-prepared contractors: of the vegetation classification work they do, 48 percent goes into a permanent data base!

Professional Personnel

The third part of the agency questionnaire related to new B.S. or M.S. foresters. These data are from 56 respondents.

How much field training do new professionals . . . receive before using the classification? The results:

No formal training at all - 11 percent (6/56). Comments: "Must pick it up on the job," or, "expected to have it in college."

<u>Response</u>	<u>Percent/Number</u>
None	11% (6/56)
4 - 8 hours	38% (21/56)
2 days	9% (5/56)
4 - 5 days	34% (19/56)
variable	9% (5/56)

I asked for some judgments on new professionals and the response level dropped to 45 of the 56 that answered part of this section. I asked respondents to indicate what qualifications they expected of new professionals and then to provide a judgment of their college preparation:

- Concepts of plant community ecology:
expected to have had in college - 100%
preparation:
good or adequate - 53% (24/45)
inadequate or apparently absent - 47% (21/45)
- Concepts of land classification using vegetation:
expected to have had in college - 93% (42/45)
preparation:
good or adequate - 38% (17/45)
inadequate or apparently absent - 62% (28/45)
- Course work leading to reliable field identification of plants:
expected to have had in college - 89% (40/45)
ability in plant identification:
good or adequate - 44% (20/45)
inadequate or apparently absent - 56% (25/45)
- Practice in college in field identification of forest communities:
expected to have had in college - 89% (40/45)
ability in field identification and classification of communities:
good or adequate - 44% (20/45)
inadequate or apparently missing - 56% (25/45)

District silviculturists indicate that the majority of new professionals lack the knowledge needed to apply or use vegetation-based land classifications. Yet, almost 50 percent of new professionals receive 2 days or less of training once on the job.

Comments: "We haven't had a new forester for so long, I can't answer", "depends on whether they're from the east or west - easterners aren't as well prepared."

UNIVERSITY QUESTIONNAIRE

A different questionnaire was addressed to the professor of forest ecology at the 11 accredited forestry schools in the far west. Answers all related to required work in forest management/forest resources (and similar) major programs at the B.S. level. Responses were received from nine schools; most replies were from professors of silviculture.

Fifty-six percent felt students need more course work on the concepts of community ecology. Asked how many hours of class time is devoted to the explanation/discussion of forest communities at the association level, the results were quite variable—from 3 to 40 hours. Those with high figures probably included field practice sessions at summer camp.

All nine schools required some time devoted to guided field work in the identification of forest communities. The average was 21 hours (about 3 field days—figuring 7 hours of class and 1 hour of travel in a class day). However, the range was great—from 6 hours to 5 days. Sixty-seven percent of the professors responding felt their students need more time on field identification of forest communities. Sixty-seven percent also felt that students needed more class time on land classification systems.

Forty-four percent felt students need more basic plant taxonomy. Yet, only three schools of the nine responding require a course in taxonomic or systematic botany. Forestry students must pick up their plant taxonomy in courses such as dendrology, range, general botany, resource ecology or at summer camp. It's not surprising that 56 percent felt their students need more time devoted to field identification of plants.

Do you feel your students are adequately prepared to put forest association/habitat type/community type classifications to use in the forestry profession? No—78% (7/9)!

The nine ecology and silviculture professors who responded were unanimously in agreement on the question: **Do you feel such classifications have a valid place in forest management practices?** All answered "yes."

Should forest agencies be charged with teaching the following aspects of land classification by vegetation (to professionals)?

Concepts of plant community ecology - No 6/9, Yes 2/9, Blank 1/9
 Concepts of land classification systems - No 8/9, Yes 1/9
 Plant identification - No 6/9, Yes 2/9, Blank 1/9
 Field practice in identifying communities - No 2/9, Yes 7/9

As a parting gesture, I chose 17 terms from the glossaries of current association or habitat type field manuals. I asked respondents to **Check the terms listed below that graduating B.S. students would be expected to define and properly apply.** Here are the terms and the positive answers from nine forestry school respondents:

accidental (species)	3
(plant) association	8
canopy coverage	9
climax	9
constancy	1
disclimax	5
ecotone	9
edaphic climax	8
fidelity	1
forb	9
graminoid	9
habitat type	9
indicator (plant species)	8
riparian	8
seral	8
succession	9
union (of plants)	1

From this we can assume that most undergraduate foresters should understand 75% of these terms. However, note that most forest habitat type and association field manuals include in the appendices plant lists per unit and include cover and constancy values - yet only one forestry school respondent checked "constancy" as a term forestry graduates were capable of defining and applying. And only one indicated that the term "fidelity" was known to students, yet fidelity is a very important aspect of community definition and of the theory of plant indicators.

SUMMARY AND RECOMMENDATIONS

The results of this survey indicate that silvicultural personnel, both from management agencies and contractors, need better and longer training courses that take 4 or 5 days in local field situations. It appears that a course designed for the specific needs of land management administrators should be developed. Attendance at such courses by forestry professors utilizing this system of land classification merits consideration.

Increased awareness by all personnel of the conceptual basis for habitat classification is needed. Training programs should stress misuse as well as proper use. Care must be taken to assure that only accurate information from the field is used in permanent data bases. Data from personnel who are untrained, self-trained or inadequately trained should not be considered.

Forestry schools can assist by providing the profession with graduates who are better equipped to understand and apply vegetation-based land classifications. In particular, many forestry students need more time devoted to supervised field identification of communities and a broader view of vegetation-based classifications as applied by an increasing number of management agencies throughout the western United States.

Both agency personnel and forestry students would benefit from better knowledge of the interaction of soils, topography and vegetation.

This survey pertained to western agency personnel in silviculture and forestry students. Yet there seems no reason to believe that other disciplines working with vegetation-based land classifications don't have problems similar to those explained. More than likely the recommendations outlined would be beneficial to all land management personnel using this system.

PLANT COMMUNITY CLASSIFICATION: FROM CONCEPT TO APPLICATION

Frederick C. Hall

ABSTRACT: Concepts for classifying plant communities by potential natural vegetation are well established (the plant association). A primary purpose for developing a plant association classification is to store and retrieve information on plant communities useful for land management. Associations may be classified according to potential species dominance, productivity, reaction to management and identifiability when disturbed. The classification is one of six kinds of information needed for land management: others are current vegetation, topography, soil, current use, and tract location. Applications to wildlife habitat management, livestock forage rating requirements, and tree production and regeneration are discussed.

INTRODUCTION

Ecosystems are composed of biotic and abiotic elements. The vegetative component, plant communities, are usually classified into potential plant associations (habitat types) based on: (1) potential vegetation, (2) productivity characteristics, (3) management considerations, and (4) identifiability in the field despite disturbance. Associations may be used to characterize livestock forage ratings, revegetation opportunities, reforestation characteristics, growth potentials for wood, shrub and herb production, and reaction of the plant community to management. When associations are identified in vegetation resource inventories, a system for storage and retrieval of information on management and ecosystem response is provided.

This paper describes an approach used by the ecology program of the USDA Forest Service in the Pacific Northwest Region for the past 25 years. The program is composed of 15 field ecologists with a three-person administrative group headquartered in the Regional Office.

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Previous papers in this symposium have discussed the theory, concepts, and methods of plant community classification. This paper introduces a few applications of the concepts and theories. The term "association" will be used for a unit of classified vegetation as discussed by Daubenmire (1952), Driscoll and others (1984), and in the Forest Service Manual (Chapter 2060).

NEEDS OF THE LAND MANAGER

A basic use of associations by land managers is to serve as a framework for storage and retrieval of ecological information (Hall 1987) which can be used to: (1) characterize plant communities, (2) refine prediction of how a plant community will react to treatment, and (3) aid in development of prescriptions to attain management goals. Associations can be used to link silvicultural characteristics of forests together with other aspects of resource management such as livestock and wildlife use. When treatments of vegetation prove successful, they may be identified by associations for further reference. Past experience is documented for each association and refined solutions are described (not prescribed) for future use.

This is accomplished by publishing a classification of plant communities including their descriptions with a key to their identification. Average site productivity potentials and management implications are included in the descriptions (Hall 1973; Hemstrom and others 1982; Hopkins 1979; Pfister and others 1977; Steele and others 1981; Volland 1985a). These are called "Plant Association Guides." Thus a silviculturist, range manager, and wildlife biologist can refer to the same Guide when considering options for treatment or land allocation.

Such a classification can aid the land manager, but it does not contain all information required. The land manager needs six kinds of resource information to make a sound decision:

1. Present vegetation: cover type, old growth forest, stagnated saplings, clearcut, current volume, presence and severity of disease, average stand diameter, forage rating, ecological status.

2. Topography (geometric classification): steepness of slope, aspect, length of slope, shape of slope (concave or flat or convex).

3. Soil characteristics: (Soil type) (Soil Survey Staff 1975): stability, ability to withstand traffic from vehicles and animals, erodability, moisture holding capacity, fertility.

4. Current use of the area: big game winter range, primary livestock range, active timber sale, endangered species area, insect outbreak.

5. Juxtaposition: location of the area in relation to roads, topographic features, water sources, or other vegetation types.

6. Association (plant community classification): characteristics of the potential plant community such as opportunities and limitations for management, plant community response to treatment, site potentials.

Used in conjunction with the other five items, associations give predictive power to land managers: potential problems may be identified and suitable treatment can be prescribed; opportunities for management can be described such as adapted species to plant or seed; and reactions of the plant community to harvest, reforestation, revegetation, fire, insects, and disease can be characterized (Arno and others 1985; Halverson and Emmingham 1982; Hopkins 1979).

CLASSIFICATION CONCEPTS IMPORTANT FOR APPLICATION

Land managers must deal with each and every acre under their jurisdiction, regardless of how typical or atypical the tract might be. Therefore, a continuum in potential natural or stable-state vegetation is a fundamental concept for classifying associations (Hall 1970). When natural potential cannot be sampled or identified, plant communities which appear to be in stable balance with their environment are selected (see Hall 1973, p. 43--Alpine fleecflower¹; Pfister and others 1977, pp. 115, 118-121--lodgepole pine; Steele and others 1981, pp. 82-85--lodgepole pine). Environmental gradients have long been recognized, such as change from north to west to south slopes, flat to steep slopes, and from low to high precipitation. Plant species react rather independently to these gradients, thus combining to form different kinds of potential natural plant communities. When combinations of environmental factors are similar, similar potential natural plant communities will result. When prominent breaks in the environment occur, such as across sharp ridgetops from north to south slopes, abrupt changes will occur in potential vegetation. Continuum gradients refer to the gradual change in potential natural communities one might see when sampling south slopes with similar soils over a 100-mile transect.

Sampling should encompass variability in the environment and plant communities to describe the natural changes in potential vegetation (Hall 1971). In order to describe an association, at least 10 sample plots are desirable. The

variability may be evaluated with multivariate statistical analysis to develop plant associations based on numerical characteristics (Volland 1974; Volland and Connelly 1978). Each association must be identifiable in the field under most degrees of disturbance. This requires inclusion of major seral vegetation and characterization of topographic and soil features in the key to aid identification in poor forage rating conditions, nonpotential ecological status, or logged forest stands.

An "association" is not a real thing but rather a useful concept. It characterizes an average condition found in many sample plots which have been grouped together according to what the investigator perceives as a basic unit meeting the needs or objectives of the classification. It is an average description of a continuum segment with maximums and minimums for species density, composition, production, and reactions to treatment. Association averages will poorly describe potential natural ecosystems located mid-way on the continuum gradient between two associations. In some people's experience, about 30 percent of the time one will find plant communities in the field that do not easily fit an association description (Hall 1973). These stands are often referred to as ecotones, intergrades, or mixtures. One recommendation is to interpret or map them as the association most limiting to management.

A fundamental question among ecologists is what differentiates one association from another. Should it be based on presence/absence of plant species? Should associations be split for differences in dominance even though the same species are present? Should they be split for differences in production? Four criteria seem to be important for establishing associations when their primary use will be to evaluate and improve land management:

1. Limited variability in species dominance. This is a particularly important criterion for range management, as discussed later.

2. Limited variability in production of trees, shrubs, and herbs with a desired 95 percent confidence limit of less than ± 20 percent of the mean.

3. Distinct from other associations for important land management opportunities and limitations such as reaction to treatment, re-establishment of trees or other vegetation, or forage rating guides.

4. Identifiable on the ground in most stages of succession. The key to identifying associations must meet this need.

In general, classifications based on species presence or dominance are divided into more types based upon the above criteria (Arno and others 1985; Hall 1987). If differences in production and regeneration potential are desired outputs, they must be considered in the development of associations. Illustrations of these criteria will be discussed in range and timber management sections later in this paper.

¹Scientific names of species are listed after the references.

WILDLIFE MANAGEMENT

Wildlife respond more to stand structure or stand condition than to potential vegetation (fig. 1). In eastern Oregon for example, elk feed in clearcut areas or natural openings, hide in sapling stands, and take advantage of thermal cover in pole- to sawtimber-sized stands (Thomas and others 1979a). To a certain extent, rough topography may substitute for hiding cover. In summer, north slopes and upper draws can substitute for thermal cover while south slopes are used in winter.



Figure 1--Clearcut in the white fir/big huckleberry association (Hall 1973). Many wildlife species using the old growth stand will not use the clearcut for reproduction and feeding.

In the Blue Mountains of Oregon, pileated woodpeckers prefer to nest in seral ponderosa pine or larch with an understory of fir. Being year-round residents, they depend upon heart-rotted snags and trees for carpenter ants, their staple winter food supply (Thomas and others 1979b). The association is important in regard to the potential opportunities characterized in its description.

For example, associations are useful in wildlife management if they have been adequately characterized for structural change with succession and reaction to treatment. They may be used to predict what kind of tree species, climax or seral, could be grown for those wildlife, like pileated woodpeckers, dependent on them.

Vegetation response to regeneration cutting will help predict production of palatable species and speed of successional change of the opening (Hall and Thomas 1979). In some cases, timber productivity can suggest opportunities and limitations for wildlife. For example, low site climax ponderosa pine will stagnate before it reaches the 70 percent crown cover desired for elk thermal cover. But on a good site where ponderosa pine is seral, it can be grown dense enough for elk thermal cover as well as to the 30-inch d.b.h. desired by pileated woodpeckers for cavity excavation.

RANGE MANAGEMENT

Range management is the art and science of grazing livestock on uncultivated vegetation in ways that best maintain or improve the plant community. Forage rating is an ecological method for determining if current vegetation has the best species dominance and production possible for the site. Traditionally it was based upon potential natural plant communities--plant associations (Dyksterhuis 1949). Recently it has been updated to include two concepts: ecological status and resource value (Range Inventory Standardization Committee 1983). Ecological status compares the existing plant community with the potential natural vegetation of the site (association). Existing vegetation is classed as early, mid, or late seral or potential.

Resource values rate the existing plant community's ability to provide products and/or services for different purposes compared to the potential possible for the site. An existing plant community may be rated as good, fair, poor, or very poor for a specified purpose. The juniper/sagebrush/wheatgrass association is an example. A site supporting potential natural vegetation might rate good for wildlife habitat and only poor for livestock forage production. Eliminating juniper and sagebrush would probably double forage production for livestock, making it a good forage rating for livestock and only poor as wildlife habitat. Livestock forage ratings based on species composition will be illustrated.

The basic concept is this. When livestock overgraze an area in potential natural vegetation, they selectively kill out the most palatable species resulting in a change of species dominance in the plant community. These species are called decreasers (Dyksterhuis 1949). With continued overgrazing, even species of low palatability are killed (palatable increasers), further changing dominance and production (Dyksterhuis 1949). Figure 2 illustrates this change in dominance, measured by percent composition, for the ponderosa pine/wheatgrass/yarrow association (fig. 3). A good forage rating may be considered to be 75 to 100 percent of potential natural species composition, fair means some overgrazing has changed the plant community to 50 to 75 percent of potential, poor means serious past overgrazing has resulted in a decrease to 25 to 50 percent, and very poor indicates most palatable species are absent--serious deterioration of the plant

community at less than 25 percent composition of potential natural vegetation.

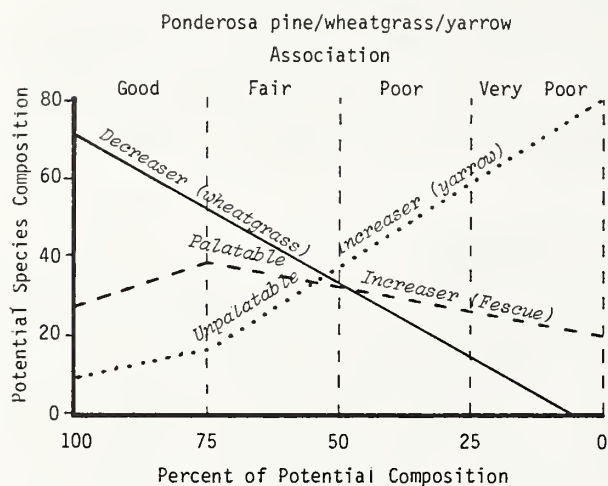


Figure 2--Method for estimating livestock forage rating based on composition. The most palatable species (wheatgrass) decreases with overgrazing. Less palatable species (fescue) increase temporarily, then decrease as they are grazed more heavily. Unpalatable species (yarrow) increase continuously.

If an association is the basis for a forage rating guide, four forage rating classes impose predetermined limits on the variability in species composition used to classify an association. In figure 2, good shows wheatgrass ranging from 53 to 67 percent composition, fescue from 26 to 34 percent, and yarrow from 6 to 14 percent composition. If a site has been correctly identified as representing the ponderosa pine/wheatgrass/yarrow association, it should have the potential for growing wheatgrass at 53 to 67 percent composition. If wheatgrass composition is less than 53 percent, one should assume that the forage rating is not good and that some past overgrazing has changed composition. Table 1 illustrates a forage rating guide for the ponderosa pine/wheatgrass/yarrow association

Table 1--Forage rating guide for ponderosa pine/wheatgrass/yarrow association based on composition of wheatgrass

Average potential natural composition:
Wheatgrass 60 percent
Fescue 30 percent
Yarrow 10 percent

Good rating	Wheatgrass	53-67%
Fair rating	Wheatgrass	35-52%
Poor rating	Wheatgrass	18-34%
Very poor rating	Wheatgrass	0-17%



Figure 3--Pondersosa pine/wheatgrass association (Hall 1973). Forage rating classes require this type be divided into more accurate associations as shown in table 2.

The concept of four forage rating classes imposes statistical limits on how an association is developed. Since good represents 75 to 100 percent of potential, the range is 25 percent for an average of 82.5 ± 12.5 percent. Remember, the association is a conceptual description that is an attempt to characterize an unknown population of potential plant communities by a limited number of samples. As an estimate of a population, it should meet some set of statistical requirements. A choice is selection of an accuracy level, for example, a 95 percent confidence limit of ± 12.5 percent of the average composition of decreaser species.

This implies that when a site is correctly identified as being able to support a certain association, that site has the potential, 95 times out of 100, of actually being able to grow a species at a calculated level of composition. In the ponderosa pine/wheatgrass/yarrow association, a correctly identified site should have the potential of growing wheatgrass at 53 to 67 percent composition (a mean of 60 ± 7 percent where 12.5 percent of the mean is $60 \times .125 = 7$). The land manager does not know if the real site potential is 53 percent, 67 percent, or someplace in between.

Sample data from stands at their natural potential showing more than 67 percent or less than 53 percent composition of wheatgrass, under this assumption, should be considered for another association. Similarly, stands showing more than 34 percent or less than 26 percent composition of fescue might form another association. Table 2 illustrates the need for three associations where wheatgrass and fescue are the two most important herbaceous species in ponderosa pine savanna.

These imposed accuracy requirements tend to create some problems. A major one is how to identify the correct association in any stage of disturbance--such as very poor forage rating--where less than 25 percent of the potential natural vegetation remains.

Figure 4 shows a plant community dominated by ponderosa pine where wheatgrass is currently 25 percent composition. Is it a poor forage rating for ponderosa pine/wheatgrass/yarrow, fair for ponderosa pine/wheatgrass/fescue, or almost good for ponderosa pine/fescue/yarrow? An ability to determine the appropriate association for a disturbed site is important. Brown topsoil, low density pine, rabbitbrush, bluegrass, and only 25 percent composition of fescue indicate a poor forage rating for ponderosa pine/wheatgrass/yarrow.

In most cases, regression analysis between site factors and species dominance suggests indicators that can be used to identify an association. In ponderosa pine communities with wheatgrass and fescue, increasing elevation, change from south to north slope, increasing slope steepness, increasing old growth basal area, and increasing darkness of the soil indicate change from wheatgrass dominance to fescue dominance (Hall 1973).

TIMBER MANAGEMENT

Two primary concerns foresters have are stand production and regeneration characteristics. Associations can be used to refine both of these. For example, table 3 compares six associations that are approximately ponderosa pine site index class 80. In addition, livestock forage and wildlife use are shown.

Table 2--Number of associations required for forage rating evaluation where ponderosa pine, wheatgrass, and fescue are major components of the plant communities

Plant Associations	*Pipo/ Agsp/ Acmi	Pipo/ Agsp- Feid	Pipo/ Feid/ Acmi
Wheatgrass	60 +7	45 +5	30 +4
Fescue	30 +4	45 +5	60 +7
Yarrow	10 +4	10 +4	10 +4

*Pipo = ponderosa pine
 Agsp = wheatgrass
 Acmi = yarrow
 Feid = fescue



Figure 4--A site dominated by ponderosa pine with rabbitbrush 5 percent cover, wheatgrass 25 percent, fescue 25 percent, bluegrass 25 percent, yarrow 25 percent composition and cheatgrass. What is the forage rating?

Ponderosa pine/bitterbrush/squirreltail-rhyolite is an association related to other ponderosa pine/bitterbrush associations but differentiated by dominance of squirreltail over other grasses, apparently a result of the white, Newberry rhyolitic pumice soil (Volland 1985a). This soil causes severe regeneration problems by frost heaving when the litter and duff are removed or even disturbed. In comparison, regeneration is a problem in the ponderosa pine/bitterbrush/long-stolon sedge association because long-stolon sedge is stimulated into active competition and full-site occupancy by site preparation (Volland 1985a). It is difficult to control because the vigorous rhizomes are generally 2- to 3-inches deep. Another regeneration problem occurs in the mixed conifer/pinegrass-ash soil association. Here extreme competition occurs in undisturbed good forage rating which requires site preparation (Hall 1973). All three associations share severe regeneration problems--but all three must be treated differently since causes of the problems are different. And each is characterized by differences in the herbaceous component--differences great enough to indicate significantly different effective environments for management.

Wood production and herbage production vary greatly between the associations considering they all fall into the site index 80 category. In addition, significantly different forage rating guides are required for ponderosa pine/bitterbrush/fescue, ponderosa pine/bitterbrush/sedge, and mixed conifer/pinegrass-ash soil (Volland 1985b). So one must return to a fundamental question. What constitutes an association? What are the criteria for splitting or lumping? How will the classification be used? Use is the key. For this

Table 3--Six associations containing ponderosa pine with a site index class of 80 comparing selected characteristics (95 percent confidence intervals)

Association:	*Pipo/ ¹ Putr/ Feid	Pipo/ ¹ Putr/ Sihy- rhyolite	Pipo/ ¹ Putr/ Cape	Mixed ¹ Conifer/ Arpa- Ceve	Mixed ¹ Conifer/ Syal/ Caru	Mixed ² Conifer/ Caru- ash soil
Status of pine:	Climax	Climax	Climax	Seral	Seral	Seral
Pine regeneration:	Easy	Severe-soil (frost heave)	Severe-sedge competition	Moderate	Moderate	Severe-grass competition
Wildlife use:	Winter-high	Low	Moderate	Summer-high	Moderate	Low
Growth basal area (ft ²) ³	98 ± 8	91 ± 25	82 ± 19	209 ± 19	169 ± 55	124 ± 9
Site index (ft)	76 ± 3	74 ± 4	84 ± 2	83 ± 2	85 ± 8	76 ± 4
Production:						
Wood (ft ³) ⁴	41 ± 4	38 ± 12	38 ± 9	97 ± 12	80 ± 32	53 ± 5
Herbage (lbs)	121 ± 19	31 ± **	51 ± 20	30 ± 16	12 ± **	330 ± 56
No. of plots:	43	3	10	21	5	33

¹ Volland 1985.

² Hall 1973.

³ Stand basal area at which dominants grow at 1.0 inch per decade in diameter (Hall 1983).

⁴ An index value computed as $SI \times GBA \times .005 = \text{ft}^3$ per acre per year.

* Pipo = ponderosa pine Sihy = squirreltail Ceve = shinyleaf manzanita
Putr = bitterbrush Cape = long-stolon sedge Syal = snowberry
Feid = Idaho fescue Arpa = greenleaf manzanita Caru = pinegrass

** Data too variable to calculate a 95 percent confidence interval.

reason, the Pacific Northwest Region's ecological classification program use four kinds of criteria for classifying an association: floristic similarity, productive similarity, similar management considerations, and identifiability in the field.

CONSIDERATIONS FOR VEGETATION MANAGEMENT

Data and interpretations for vegetation management must go into the classification so that management implications can be drawn from the classified units (associations). Classification of associations (lumping or splitting) can be influenced by factors in addition to presence or dominance of plant species.

Differences in productivity are just as ecologically oriented as are differences in species dominance (Hall 1971; Stage 1973, 1976). Regeneration characteristics are ecologically based as are revegetation opportunities (Halverson and Emmingham 1982). And seral reaction of plant communities are also environmentally influenced (Arno and others 1985).

Precision in association classification in the Pacific Northwest is designed for project level application, treatment of 10- to 40- acre tracts. National Forest and Regional plans require various

groupings of associations for their broader application to 1,000- to 5,000- acre units. One problem has been to adequately define the question of what is wanted from the groups. Generally, a map of associations has limited value above the Ranger District level (see Hemstrom and Frazier, these proceedings). Another problem is that management differences that could be used to distinguish associations may be unknown at the time of classification. This requires revision of the classification on a periodic basis.

SUMMARY

The primary purpose of plant association classification for land management is to store and retrieve management-related information used to characterize plant communities, predict plant community response to treatment, and aid prescription of treatment for attainment of a desired goal. Associations are used in conjunction with present vegetation, topography, soil, current use, and tract location to refine management decisions. A philosophy of a continuum in potential natural vegetation is assumed where sampling should encompass variability in vegetation and environment. Four criterion are used to establish an association: similar species dominance, limited variability in production, significant consideration for management, and identifiability in any stage of disturbance.

Wildlife respond more to stand condition or structure than to potential vegetation. Associations are useful in predicting habitat changes with succession or management and in characterizing opportunities and limitations of treatment to enhance wildlife habitat. Range management uses associations for forage rating guides that are based on species dominance or productivity. Four forage rating classes based on species dominance impose strict accuracy limits on composition of dominant species. This predetermined limit on variability must be a criteria for association classification. Associations are used in timber management to refine production estimates and depict regeneration characteristics in conjunction with other resource values such as herbage production and wildlife habitat.

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PLANT SPECIES MENTIONED

Alpine fleece flower	<u>Polygonum phytolaccaefolium</u> (Mein. ex Small)
Big huckleberry	<u>Vaccinium membranaceum</u> (Dougl. ex Hook)
Bluegrass	<u>Poa pratensis</u> (L.)
Bitterbrush	<u>Purshia tridentata</u> (Pursh.)
Ceanothus	<u>Ceanothus velutinus</u> (Dougl. ex Hook)
Cheatgrass	<u>Bromus tectorum</u> (L.)
Douglas-fir	<u>Pseudotsuga menziesii</u> var. <u>glauca</u> (Beissn.)
Fescue	<u>Festuca idahoensis</u> (Elmer)
Fir	<u>Abies grandis</u> , <u>Pseudotsuga menziesii</u>
Juniper	<u>Juniperus occidentalis</u>
Larch	<u>Larix occidentalis</u> (Nutt.)
Lodgepole pine	<u>Pinus contorta</u> var. <u>latifolia</u> (Engl. ex Louden)
Long-stolon sedge	<u>Carex pennsylvanica</u> (Boeck.)
Manzanita	<u>Arctostaphylos patula</u> (Greene)
Mixed conifer	<u>Abies</u> spp., <u>Pseudotsuga</u> , <u>Pinus</u> spp.
Pinegrass	<u>Calamagrostis rubescens</u> (Buckl.)
Ponderosa pine	<u>Pinus ponderosa</u> (Dougl. ex Loud)
Rabbitbrush	<u>Chrysothamnus nauseosus</u> (Pall.)
Sagebrush	<u>Artemisia tridentata</u>
Snowberry	<u>Symphoricarpos albus</u> (Blake)
Squirreltail	<u>Sitanion hystris</u> (Nutt.)
Wheatgrass	<u>Agropyron spicatum</u> (Scribn. & Smith)
White fir	<u>Abies grandis</u> (Lindl.)
Yarrow	<u>Achillea millefolium</u> (L.)

CLASSIFICATION AND MODELS OF SUCCESSION

David W. Roberts and Penelope Morgan

ABSTRACT: Approaches to the study of successional vegetation are compared and evaluated. Mechanistic and empirical philosophies are contrasted, as are classification and modeling methods. Examples are drawn from successional studies in the northern Rocky Mountains of the United States. An approach that takes advantage of the strengths of the different approaches is recommended for future work.

INTRODUCTION

There are almost as many methods for studying succession as there are investigators. The two most common methods, classification and modeling, have different objectives and emphasize different aspects of succession. Either of these two methods may be employed under a mechanistic or empirical philosophy, and the choice of philosophy will also influence the results. The objective of this paper is to compare and evaluate these contrasting approaches to the study of vegetation dynamics. We illustrate the relative advantages and disadvantages with examples of succession research in the northern Rocky Mountains. We focus primarily on applied succession research, but generally omit stand development and growth-and-yield models developed primarily for timber management objectives.

EMPIRICAL AND MECHANISTIC PHILOSOPHIES

Empirical classifications or models are based primarily upon observations of the relations between chosen variables, without explicit representation of the mechanisms of succession. Typically, large numbers of vegetation samples are observed under a random or stratified-random sampling scheme; the observed variables are chosen based on experience and past research. The vegetation samples are analyzed statistically; multivariate procedures are commonly used. The classification or model then summarizes the observed relations.

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Mechanistic classifications or models are based on a chosen theory of the causes and mechanisms of succession, such as Noble and Slatyer's (1980) concepts of inhibition, tolerance, and facilitation or Botkin's (1981) concepts of differential response to resource availability. A conceptual classification or model is developed from the theory, and vegetation is sampled to calibrate or to test the conceptual classification or model. The structure of the mechanistic model or classification is determined by the theory, rather than by observation.

No existing research falls entirely into either school. Instead, most are situated along a continuum between the poles (fig. 1). Our distinction is deliberately polar to heighten the contrast between studies using predominantly one of the two philosophies.

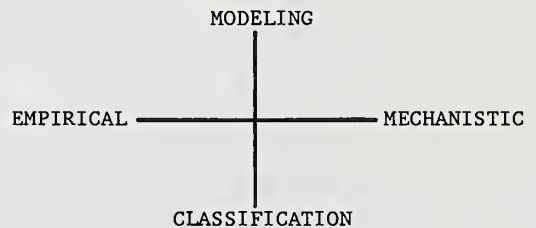


Figure 1--Contrasting approaches to studies of succession.

SUCCESSIONAL VEGETATION CLASSIFICATION

Classification of variability in natural vegetation has proven useful in land management (Layser 1974). Classifications of potential vegetation have been developed for much of the Rocky Mountains and northwestern United States (Pfister 1982). These classifications have demonstrated that despite controversy surrounding the inherent nature of vegetation distribution, classification provides a framework for communicating and enhancing ecological understanding.

It seems logical, therefore, that classification may also prove useful for describing successional vegetation, especially if the vegetation is stratified by plant association (Steele 1984). This reduces the variability among seral communities and identifies the endpoint of succession, the potential vegetation type.

Empirical Classifications

Empirical classifications are commonly developed using multivariate statistical techniques, such as cluster analysis and ordination. These techniques can be used to determine successional classes objectively and to summarize the characteristics of these classes. The techniques are well understood and this approach is efficient, leading to relatively robust results. Although investigator bias is minimized, it should not be assumed that total objectivity is achieved, for selection of variables and choice of analyses influences the structure of the resulting classification.

The primary limitation from an operational point of view is the difficulty of extrapolating results. Because empirical analyses are not based on mechanism, it is difficult to determine where outside the original study area the results may apply. Even within the study area, there is no basis for predicting vegetation dynamics under conditions not previously observed. This can lead to a multiplicity of classifications, each of which is specific to a narrow range of environments, disturbance types, and vegetation.

This philosophy has been employed in classification of successional vegetation by Arno and others (1985).

Mechanistic Classifications

The mechanistic approach employs ecological theory to predetermine the structure of the classification. The chosen theory is used to generate predictions about the temporal behavior of vegetation; the predictions are then organized into classes on the basis of similar predicted outcome. Unfortunately, there is no universally accepted ecological theory to employ, and subjective choices must be made between competing hypotheses or theories. Potentially, this leads to investigator bias, as these choices jointly determine the structure of the classification. If the chosen theory is subsequently discredited, or not accepted by other scientists, the utility of the classification becomes suspect.

The primary advantage of the mechanistic approach is the greater ease with which results can be extrapolated. As long as the same mechanisms are operable, the results should apply outside the immediate study area. Additionally, it is possible to hypothesize combinations of environmental factors or disturbance regimes never observed, and to predict vegetation composition for these sites. Then, if these new sites are observed, they are already included in the classification system.

The primary disadvantage of the mechanistic approach is that even with a few essential mechanisms, numerous successional community types may be predicted, some of which are rare or nonexistent (Steele 1984). This leads to two problems. First, the classification may be overly complex, and given our limited understanding of

the relationships involved, a simpler approach may be preferable. Second, there may be many classes with too few samples, which limits the reliability of predictions about the characteristics of such classes.

Huschle and Hironaka (1980), Steele (1984), and Steele and Geier-Hayes (1987) used the mechanistic approach to classify successional vegetation.

MODELING OF SUCCESSIONAL VEGETATION

Succession models predict changes in vegetation with time, and range from conceptual models (Cattellino and others 1979, for example) to detailed computer models (for instance, see Keane 1987). The predicted species composition may be based upon the response of individual species, or may be based on species groups or life forms. Many models have focused exclusively on tree species, but a few have been more comprehensive.

Empirical Models

In empirical succession models, future vegetation composition is predicted based on observed relationships of site attributes, disturbance characteristics, existing vegetation, and other variables. Many are regression models, which predict the abundance of one or more species (for example, Irwin and Peek 1979; Keane 1987). Several distinct regression models may be hypothesized; these can be tested to see which yields the best predictions. Alternatively, the probability of transition from one successional community to another can be measured and employed in a Markov chain model (Hulst 1979), or the rate of transition can be used in a differential equation model (Shugart and others 1973).

Few complex models are entirely empirical. For instance, the Stand Prognosis Model projects tree and stand development (Wyckoff 1986; Wyckoff and others 1982), tree regeneration (Ferguson and Crookston 1984; Ferguson and others 1986) and occurrence, biomass, and cover of some understory species (Moeur 1985), based on site attributes, habitat type, and disturbance or management. The functional relationships were empirically estimated using regression (usually nonlinear) techniques, but the particular functions were constrained by known or hypothesized relationships. Thus, models with the "best fit" statistically were not used if their predictions were inconsistent with available qualitative knowledge (Stage 1988).

Empirical models share most of the advantages and disadvantages of classifications developed under the same philosophy. These models benefit from the widespread availability of statistical tools, and they are relatively objective and efficient. Extrapolation of model predictions may be seriously in error, however, and care must be taken to avoid overfitting statistical models by using too many independent variables with too few samples (Verbyla 1986).

It is important that the assumptions on which a given statistical technique is based are appropriate to the vegetation structure and distribution, or that the technique is sufficiently robust. For instance, many models are based on an assumption of linear or monotonic response of vegetation composition to environmental gradients or disturbance factors, which may be inappropriate (see Roberts and Cooper, this proceedings).

Mechanistic Models

Many forest simulation models have been developed under the mechanistic philosophy. Botkin and others (1972) pioneered a model paradigm, JABOWA, that simulates the birth, growth, and death of individual trees in a stand. This model explicitly incorporates the effects of light and moisture availability on photosynthetic response and growth rate. Related models have included other environmental factors ranging from nutrient availability (Aber and Melillo 1982; Pastor and Post 1986) to fire response (Kercher and Axelrod 1984), as well as the long-term effects of forest management practices (Aber and others 1979, 1982).

While this model paradigm has provided insight into the possible effects of disturbance or management in a variety of forest ecosystems (Shugart 1984), there are some practical limitations. First, the models are data intensive, requiring quantitative estimates of each species' response to environmental factors and other autecological information. Often these data do not exist and may be difficult to obtain. Second, the model structure is designed primarily for tree species. While it should be possible to modify the program for other life forms, it will be difficult given the current complexity of the model. Third, the model is computationally intensive. The model is stochastic and requires averaging the numerous replicate simulations to produce estimates of expected values. Steinhorst and others (1985) simulated shrub response to clearcutting and burning. The model combines stochastic and deterministic elements to predict the probability of establishment and subsequent growth of individual shrub species. Predictions are made of the shrub community composition for 15 years following burning. Predicting response of only a part of the vegetation to only some kinds of disturbance may be more effective than developing larger, more general models.

Other mechanistic models are based on the vital attributes concept of Noble and Slatyer (1980). These models produce qualitative estimates of tree species abundance (Cattellino and others 1979) or semi-quantitative predictions of abundance of all species (Kessell and Potter 1980) for vegetation subjected to recurrent disturbance. These models are graphical, rather than computer-based, which increases their utility and intuitive appeal for many users. They lack detail necessary for some purposes, however. Roberts (1987) developed a stochastic simulation model based on the vital attributes paradigm which removes some of the limitations, but a computer is required. These

models produce semi-quantitative predictions useful for land managers, they have minimal data requirements, which can easily be determined or estimated, and they are computationally efficient.

DISCUSSION

Developers and users of successional classifications and models need to be aware of the advantages and disadvantages of each method and philosophy. The purpose for which the classification or model will be used, time available, and costs of development will constrain the choices. Careful design based upon extensive forethought will greatly increase the utility of the end result.

Empirical Versus Mechanistic Philosophies

Throughout this paper, we have deliberately emphasized distinctions between philosophies of succession research. In practice, these philosophies are often combined very effectively. Mechanistic classifications or models require empirical data for calibration and validation. Empirical classifications or models require theory to suggest which variables are essential for inclusion and to evaluate model behavior.

Empirical methods are well suited to specific applications, or to situations where the relevant theories are not sufficiently developed to guide mechanistic model or classification development. These methods are based on observation, which imparts two critical characteristics. First, sampling design, (the degree of randomization, the stratification criteria, and the definition of the target population) is very important, as it determines the observations made. Second, the extent to which observations of the past and present provide a reasonable basis for predicting the future must be determined. The conditions under which vegetation develops presently are different from the past. Widespread fire suppression is ecologically unprecedented, and silvicultural practices produce vegetation communities that may never have existed previously.

Mechanistic approaches are appropriate for more general or comprehensive applications, or for problems where detailed data for development of an empirical classification or model are lacking. Mechanistic approaches are based on theory, and the success of this approach will depend on the applicability of current theories to the local situation, and the skill of the developer in implementing the selected theories as a model or classification.

Research in natural resources has generally shown that when the primary objective is accurate prediction of specific variables, empirical approaches are superior. When the primary objective is increasing our understanding of complex systems, or predicting the behavior of a system outside the range of observation, mechanistic models are preferable.

Classification Versus Modeling

Classification of successional vegetation can produce benefits similar to those derived from classification of potential vegetation: increased ecological understanding and a framework for communication. However, successional vegetation is dynamic, so classifications have increased utility if there is an indication of how long a community will stay in a given class, and to which class it may subsequently belong. Ideally, we would like to know the entire sequence of successional development, called the pathway by Arno and others (1985). If the pathway is branched, probabilities can be assigned to the multiple pathways of successional development.

Alternatively, simulation models provide a more natural analog for successional dynamics. There now exists a considerable knowledge base for the development and application of such models. Many existing models of succession have a mix of resolution; individual trees are modeled in great detail while detail on other life forms is minimized or omitted. Many of these models also have extensive data requirements, and produce information difficult to interpret in a management context.

RECOMMENDATIONS

Based on our assessment of the relative advantages of each approach and the information needs of land managers, we suggest the following. Employing a mechanistic approach, develop a simple conceptual model which identifies the main successional pathways and partitions the successional vegetation into a moderate number of possible states or classes. When defining pathways, limit each attempt to the possible pathways that lead to a single plant association. Ensure that the model is comprehensive and general enough to accommodate the entire range of possible successional communities. Then, from the conceptual model develop a simple simulation model that predicts the rate and pathway of transition among the individual classes or states based upon responses of individual or groups of species. Then, employing an empirical approach, collect sufficient data to characterize the vegetation composition for the observed states of the model. Additional resource values (such as big game hiding cover or recreation potential) can be predicted indirectly from the predicted vegetation composition and structure. Validate the model based upon data independent of that used in model construction, and refine the model where necessary.

We believe this approach will produce tools useful to land managers in a broad range of vegetation types with relatively few years of effort. It will incorporate our understanding of successional processes, yet be efficient in terms of vegetation sampling and analysis. The models will be sufficiently simple that the computational requirements will be easily met, and will produce information in a form useful to land managers.

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INFLUENCE OF BIOLOGICAL LEGACIES ON SUCCESSION

Jerry F. Franklin and Charles B. Halpern

ABSTRACT: Survival of indicator plant species was addressed in a long-term study of succession after clearcutting and slash burning in Douglas-fir forests. Very dry or very moist habitats returned to classifiable states more rapidly than less harsh environments. Areas with sparse understory before logging were slowest to return to classifiable states.

Predisturbance ecosystems typically have major influences on the pathways and rates of succession after a catastrophic disturbance. Much of this influence is related to "biological legacies," organisms or organic structures and influences that persist through the disturbance. Indeed, a disturbance can be viewed as an editing process in which selected elements of the predisturbance ecosystem are carried into and influence the recovery process. The importance of biological legacies has been demonstrated in seres after natural large-scale catastrophic events (for example, the eruption of Mount St. Helens) and after typical forest clearcutting.

Important biological legacies include living organisms, structures, and spatial patterns. Living legacies include green plants, animals, seed banks, and fungi. Important animal and fungal components may include pests and pathogens, as well as mycorrhizal fungi. Numerous organisms survived the catastrophic eruption of Mount St. Helens as a result of many different strategies and circumstances (Franklin and others 1985). Dead organic legacies include fine organic matter, as well as structures such as standing dead trees, downed boles (coarse woody debris), and large soil aggregates. Coarse woody debris is critical as habitat for many heterotrophs and for many other ecological functions (Harmon and others 1986). Spatial patterns include soil patterns that are associated with individual trees and patterns in

composition and density of understory vegetation associated with overstory canopy density (shading). Western hemlock and western redcedar provide an outstanding example of the contrasting effects of tree species on soil chemical, physical, and microbiological properties (Alban 1969; Turner and Franz 1985). Areas of greater sunlight (gaps) and of dense shading (antigaps) produce contrasting legacies. For example, at the H. J. Andrews Experimental Forest in the western Cascade Range of Oregon, heavily shaded areas belonging to the *Tsuga heterophylla* series (referred to as the *Coptis laciniata*, or Goldthread community, by Dyrness 1973) have depauperate understories; after clearcutting, tree regeneration is typically more successful on such sites because of the lack of competing herbs and shrubs.

A major issue in vegetation classification is identification of habitat types early in succession. Hence, a biological legacy of particular interest is persisting indicator species. Their survival was addressed in a long-term study of succession after clearcut logging and slash burning in Douglas-fir forests at the H. J. Andrews Experimental Forest (Dyrness 1973; Halpern 1987). A total of 192 permanent 2 x 2 m sample plots were established in undisturbed forest; changes in vegetation have been observed since the plots were logged and burned during 1962-66.

Analyses considered the period of time before plots returned to an identifiable state, with habitat type and disturbance intensity as major variables. Results showed that more extreme habitats (very dry or very moist) returned to a classifiable state more rapidly than modal sites, partially because modal environments depend more heavily on relative coverage of widespread species for identification (i.e., lack high-fidelity species). Areas that had depauperate understories before logging (antigaps) were slowest to return to an identifiable state after disturbance. Generally, recovery period increased with increasing disturbance intensity.

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CLASSIFICATION AND PREDICTION OF SUCCESSIONAL PLANT COMMUNITIES

USING A PATHWAY MODEL

Robert E. Keane

ABSTRACT: This paper describes a successional classification system that identifies successional communities and sequences of communities called pathways within a habitat type. This classification links treatment, site, and vegetation factors to construct a conceptual model of succession for four habitat types common to west central Montana. A computer model (FORSUM) was developed from this classification system that predicts coverage of plant species based on treatment and predisturbance plant composition. Testing shows that FORSUM averaged 74 percent accuracy in predicting species cover. Predictions from this model are useful in land management and planning. FORSUM is widely available for several computer systems.

INTRODUCTION

Land classifications using the habitat type approach (for example, Pfister and others 1977) describe the potential vegetation of a land unit but provide limited information on the composition of the seral communities occupying much of the area within a habitat type. Identification of successional communities is important in land management planning because types of silvicultural treatments strongly influence successional community sequences across the landscape (Cholewa and Johnson 1983; Fischer and Bradley 1987; Stickney 1980; Zamora 1975). Understanding successional sequences, termed "pathways" in this paper, is of great importance for management of timber, wildlife habitat, range, watershed and recreational resources. Classification of seral communities will allow a means of identifying and mapping current vegetation. Arranging the sequence of seral communities along a pathway and then quantifying species cover changes along the pathway provides a useful predictive tool for forest land management.

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The conceptual successional pathway model presented in this paper is composed of a discrete set of vegetation communities sequentially linked in succession-time by successional pathways (Arno and others 1985). These pathways begin with pioneer plant communities arising immediately after a major disturbance and terminate with the near-climax or long-term stable community. This approach is quite similar to that taken by Cattellino and others (1979) and Kessell and Fischer (1981). An important feature of this conceptual pathway model is that predisturbance vegetation, site factors, and disturbance characteristics are recognized as influencing pathway origin and direction. This facilitates the quantification of the conceptual model to an empirical model using the data collected for the classification (Keane 1987).

This paper describes how the pathway approach was used in the development of a successional community classification system for four major habitat types in west central Montana. In addition, an accompanying computer model, called FORSUM, is presented. This computer model was created from the conceptual pathway model using empirical data. It is a useful predictive tool applicable to many resource management concerns.

CONCEPTUAL MODEL

Sampling--Development of this pathway model required extensive data collection. Many plant communities resulting after different stand-replacing silvicultural treatments (table 1) or wildfire were sampled using techniques described by Arno and others (1976) and Pfister and Arno (1980). In addition, adjacent mature and postdisturbance communities on the same physical site were sampled to reduce variability between individual sites within a habitat type (Arno 1981; Zamora 1975). Site characteristics, disturbance histories, and coverages of individual species were recorded for each stand (Arno and others 1985).

To minimize regional floristic differences, vegetation sampling was restricted to an area of approximately 5 million acres in western Montana, relatively homogeneous in geology, macroclimate, and physiography (fig. 1). Sampling was confined to four common habitat types (table 2) which comprise over half of the forested acres in this area.



Figure 1--Sampling area for the succession classification and computer model. Application of the classification or model outside the study area is not advisable.

Classification--Data collected from 774 stands were scrutinized to determine if successional development could be described fully, based upon the existing habitat type classification (Pfister and others 1977). In some cases additional refinement of habitat types at the phase level was made to define more appropriate potential climax types for this limited area (Arno and others 1985). Then, based upon results of ordination analyses (Gauch 1984), synthesis table analyses (Mueller-Dombois and Ellenburg 1974), and index-of-similarity calculations (as outlined in Pfister and Arno 1980), sampled stands were grouped into community types based on dominant or diagnostic plant species.

Community type names were assigned by identifying the dominant overstory and the diagnostic undergrowth plants. For example, a community dominated by Pinus contorta (PICO or lodgepole pine) in the overstory and Calamagrostis rubescens (CARU or pinegrass) in the undergrowth would be named PICO/CARU. Communities with no overstory cover had only one species in the name (e.g. CARU), and communities with shared dominance by two or more species had hyphenated names (for example, PICO-PSME/CARU-XETE).

Table 1--Types of silvicultural treatments and natural disturbances used in the succession classification and model. All disturbances can be initiated at one of three severities. The severities are low or light, moderate or medium, and high or heavy. Criteria used to assess disturbance severity are outlined in Keane (1987)

Treatment Code	Treatment Type
WF	Wildfire; must be a stand-replacing fire.
BB	Clearcut and broadcast burn; all trees must be removed.
MS	Clearcut and mechanical scarification; all trees are removed. Includes pile-and-burn treatments.
NP	No site preparation implemented on site after clearcut.

Table 2--List of potential vegetation types included in the successional classification and model. The list includes the phases of each type that was sampled. See Arno and others (1985) for explanation of the potential vegetation types as they relate to habitat types

Potential Veg Type	Phase Code	Scientific Name	Common Name
PSME/PHMA	DRY	<i>Pseudotsuga menziesii</i> / <i>Physocarpus malvaceus</i> , dry	Douglas-fir/ ninebark, dry
PSME/PHMA	MOIST	<i>Pseudotsuga menziesii</i> / <i>Physocarpus malvaceus</i> , moist	Douglas-fir/ ninebark, moist
PSME/VAGL	XETE	<i>Pseudotsuga menziesii</i> / <i>Vaccinium globulare</i> , <i>Xerophyllum tenax</i>	Douglas-fir, huckleberry, beargrass
ABLA/XETE	VAGL	<i>Abies lasiocarpa</i> / <i>Xerophyllum tenax</i> , <i>Vaccinium globulare</i>	subalpine fir/ beargrass, huckleberry
ABLA/XETE	VASC	<i>Abies lasiocarpa</i> / <i>Xerophyllum tenax</i> , <i>Vaccinium scoparium</i>	subalpine fir/ beargrass, whortleberry
ABLA/MEFE	WARM	<i>Abies lasiocarpa</i> / <i>Menziesia ferruginea</i> , warm	subalpine fir/ menziesia,
ABLA/MEFE	COLD	<i>Abies lasiocarpa</i> / <i>Menziesia ferruginea</i> , cold	subalpine fir/ menziesia, cold

Pathway Delineation--Successional pathways were identified by analysis of the data for all stands within each community type for a specific habitat type phase. First, stands within individual pathways were ordered along a successional gradient using the following stand data: 1) tree canopy cover (%); 2) average d.b.h. (diameter at breast height) of dominant trees (inches); 3) basal area (ft²/acre); and 4) stand age or years since last major disturbance. These stand characteristics were used to define five structural stages or nodes of successional development along a pathway (fig. 2). These ordered communities were then sorted into pathways based on species composition and autecology of the diagnostic plant species. A hypothetical example of pathways within a habitat type is shown in figure 3. Stepwise keys using species coverage as criteria were constructed to identify the successional pathways (fig. 4)

It was assumed all successional pathways converged on or near a climax community type (habitat type or phase) defined by a particular vegetational composition (Arno and others 1986). The point along the successional gradient at which pathways converge was estimated based upon inspection of the composition of stands at different ages. The resulting classification contains community types arranged along succession pathways by structural stages (fig. 5).

Relating Treatment to Pathway--After the classification was developed, the kind and severity of treatments were linked to the initial, posttreatment community type of each pathway. Treatment histories, site characteristics and species compositions of sampled stands in the paired post- and pre-disturbance communities were inspected to determine which kinds of conditions were associated with the origin of a given pathway (Arno and others 1985, Keane 1984). Although treatments were often not strongly correlated with pathway origin, a set of guidelines was formulated to describe the usual conditions or treatments apparently influencing successional direction. These guidelines were then integrated into the classification as a part of the successional diagram called the Conditions or Treatment Box (fig. 6).

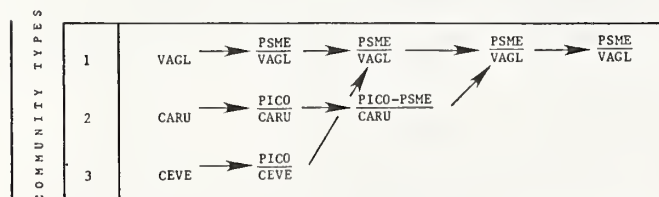


Figure 2--An example of three successional pathways within a hypothetical habitat type phase or potential vegetation type. Each pathway is composed of five successional communities linked by arrows. Species code definitions: VAGL - Vaccinium globulare, CARU - Calamagrostis rubescens, CEVE - Ceanothus velutinus, PSME - Pseudotsuga menziesii, and PICO - Pinus contorta.

Stand characteristics	STRUCTURAL STAGES				
	Shrub-herb	Sapling	Pole	Mature seral forest	Old-growth forest
Tree canopy cover (percent)	0-15	15-90	50-90	50-80	50-70
d.b.h. of dominant trees (inches)	0-1	2-5	6-10	11-15	16-25
Basal area (ft ² /acre)	0-1	2-100	100-250	100-250	150-250
Age (yr)	5-15	15-30	30-100	100-200	200-300

Figure 3--Structural stages describing a succession pathway in time. Example ranges of stand characteristics are shown within the diagram.

Final Classification--The successional classification for each habitat type phase includes the successional diagram (fig. 5), pathway keys (fig. 4), treatment associations (fig. 6), plant composition and coverage tables by community type, and a summary of individual species' response to disturbance (Arno and others 1985). The classification can be used to identify the community type of an individual stand or to predict the kinds of communities that might result after alternative silvicultural treatments.

The classification primarily provides qualitative information to the land manager in the form of a conceptual model composed of community type names and descriptions.

EMPIRICAL MODEL

An empirical computer model was constructed from the successional classification to improve its use as a predictive tool in land management. This computer model, called FORSUM (a FOREst Succession Model), predicts changes in canopy cover for 74 plant species in the four habitat types listed in table 1 (Keane 1987). FORSUM uses various site and vegetation characteristics of a predisturbance stand, along with a chosen treatment and intensity, to predict species cover from year 5 to year 300 after disturbance. The model produces both graphic and tabular output.

KEY TO SUCCESSIONAL COMMUNITY TYPES WITHIN A HABITAT TYPE PHASE

Instructions: Select most appropriate pathway number for the stand in question through use of the undergrowth key below. Stop at the first requirement that fits.

Requirement	Pathway number
a. <u>Ceanothus velutinus</u> (CEVE) >5% canopy cover	3
b. <u>Calamagrostis rubescens</u> (CARU) or <u>Carex geyeri</u> (CAGE) or their combined coverages >25%	2
c. <u>Vaccinium globulare</u> (VAGL) >5% canopy cover	1

Figure 4--An example successional pathway key in the successional classification.

S T R U C T U R A L S T A G E S						
C O M M U N I T Y T Y P E S	Row No.	Shrub-herb	Sapling	Pole	Mature seral forest	Old-growth forest
	1	VAGL	PSME VAGL	PSME VAGL	PSME VAGL	PSME VAGL
	2	CARU	PICO CARU	PICO-PSME CARU		
	3	CEVE	PICO CEVE			
S T A N D C H A R A C T E R I S T I C S						
Tree canopy cover (percent)		0-15	15-90	50-90	50-80	50-70
d.b.h. of dominant trees (inches)		0-1	2-5	6-10	11-15	16-25
Basal area (ft ² /acre)		0-1	2-100	100-250	100-250	150-250
Age (yr)		5-15	15-30	30-100	100-200	200-300

Figure 5--Example of the final classification complete with stand characteristic definitions and pathway keys.

Conditions or treatment (To use these predictions, follow numerical sequence)	C O M M U N I T Y T Y P E S	Row No.	Shrub-herb	Sapling	Pole	Mature seral forest	Old-growth forest
No site preparation or light burn		1	VAGL	PSME VAGL	PSME VAGL	PSME VAGL	PSME VAGL
Heavy scarification or hot burn		2	CARU	PICO CARU	PICO-PSME CARU		
Medium or hot burn with CEVE seed in soil		3	CEVE	PICO CEVE			

Figure 6--Example of the integration of treatment type and severity to successional pathway origin. Conditions and treatment box is shown on the left of the diagram. For example, the CEVE community type results after a moderate to high severity broadcast burn or wildfire in a stand containing CEVE seeds in the soil.

Model Description

Model Construction--Plant species are established in the model based upon their reproductive and survival strategies, shade tolerance, and life form. The type and severity of treatment can also influence species establishment. For example, *Ceanothus velutinus* (CEVE) produces seeds which remain viable in the soil for long periods of time and germinate only after moderate to severe fires. The model would predict CEVE cover only if the treatment were a broadcast burn or wildfire of moderate to high severity, and only if CEVE seeds were present in the soil. Presence of CEVE seed is determined by evidence of CEVE plants at or near the site in question. Seed sources for some herbaceous and shrub species are assumed to be always present on-site because wind will frequently disperse their seeds over large areas.

Changes in coverages of individual species over succession time are calculated from regression equations for each species. These equations were built by first stratifying all stand data in a habitat type phase or potential vegetation type by successional pathway. A multiple regression analysis was then performed on the stratified data for the most frequent or dominant plant species. For instance, eight possible successional pathways were identified in the PSME/VAGL, XETE habitat type phase. Forty species were selected for modeling in these pathways. Since there is a regression equation for each species and pathway, 320 equations are used to predict species cover in this habitat type phase. Independent variables used in the regression analysis included site characteristics (for example, elevation), stand age, kind and severity of treatment, and predisturbance coverage data. The regression equations were coded and entered into a computer file that is accessed during program execution.

Appropriate regression equations used for predicting canopy cover are selected by computing a potential successional pathway for the postdisturbance stand. Individual plant coverages collected from the site to be disturbed and treatment type and severity to be implemented are used as criteria for selecting the pathway. These criteria are incorporated into FORSUM using a series of program commands.

Model Testing--FORSUM was tested extensively using additional field data collected from the study area (fig. 1). In the test, adjacent mature and postdisturbance stands were sampled using methods defined by Arno and others (1986). The predisturbance plant coverage values and site parameters from the mature stands were used as inputs to the model. Next, FORSUM was used to predict postdisturbance plant coverages. Finally, the sampled postdisturbance coverages in cover classes (Pfister and others 1977) were compared with the FORSUM predictions.

Testing results, reported in percent correct, showed the model averaged 74 percent accuracy in the four habitat types. Overall accuracy ranged from 69 percent to 78 percent for 68 sites.

However, the model averaged 87 percent accuracy within (+ or -) one cover class (Keane 1987). For many aspects of land management planning a high degree of accuracy for species coverages is not essential. When the two smallest cover classes (T= 0-1% coverage and 1= 1-5% coverage) in FORSUM were combined the accuracy was 85 percent. Succession following clearcutting and broadcast burning or mechanical scarification treatments is more accurately predicted than wildfire or clearcutting with no site preparation (79% as compared to 71%). Tree coverages are more difficult to predict (65% accurate) as compared to undergrowth species (82% accurate).

Correctly identifying successional pathway is a sensitive or critical procedure in FORSUM. If the pathway is misidentified, the wrong regression equations are used to predict cover. However, during model testing the successional pathway was never misidentified. The regression equations are the foundation of the model and will need refinement as additional data become available.

Model Discussion

Model Use--Input data for FORSUM are entered using a "user-friendly" interactive data entry routine. Users can choose from two skill levels for entering input data -- "novice" or "experienced". The user then can select any one of the four treatments in table 2 and implement the treatment at one of the three severities. Input data are typically plant coverage values and site parameters collected from a mature stand that the user wishes to study. The user can project successional cover up to approximately 300 years depending on habitat type phase. FORSUM presents cover predictions in tabular and graphic form and output can be printed on the line printer and/or computer terminal.

Model Access--FORSUM is currently being managed by the Ecosystem Management Program of the USDA Forest Service Northern Region in Missoula, Montana. The computer program, written in the FORTRAN 77 programming language, is operable on the Data General MV series minicomputers, and also on the UNIVAC mainframe in Fort Collins, Colorado. The model has been linked to several vegetation data base management systems to simplify input data entry and allow easy access to vegetation information for a potential stand to be input into FORSUM.

Model Future--FORSUM was designed so that additional habitat types can be implemented with minimal effort. Although development of the species-specific regression equations is data intensive (requiring time for vegetation sampling and community analysis), regression analysis can be accomplished fairly easily. Development of the regression equations for the two phases of the subalpine fir/beargrass habitat type took one analyst approximately 5 weeks working full time. However, analysis can become more difficult as species diversity increases within a habitat type phase.

The Northern Region's Ecosystem Management Program now maintains FORSUM and intends to expand it to cover several new habitat types. Those habitat types scheduled to be added to FORSUM and for which some successional data have been collected include PSME/SYAL (Douglas-fir/snowberry), PSME/CARU (Douglas-fir/pinegrass), PSME/LIBO (Douglas-fir/twinflower), and ABGR/ASCA (grand fir/wild ginger). Others which have been selected but not sampled as yet are ABLA/CLUN (subalpine fir/queencup beadlily), THPL/CLUN (western redcedar/queencup beadlily), and TSHE/CLUN (western hemlock/queencup beadlily). FORSUM has been linked to the ECODATA data base management system for efficient program execution. The Ecosystem Management Program is also in the process of generating guidelines for the development of the regression equations needed in FORSUM.

Additional silvicultural treatments and vegetation variables will also be included in FORSUM. FORSUM will soon be able to predict species coverages after partial cuttings (shelterwood cuttings for example) and prescribed burns. And, in addition to plant coverages, predictions of average shrub height, tree density by species, and exposed mineral soil as a percentage of total area will be generated from FORSUM.

Model Implications--There are many potential uses for FORSUM. Foresters might use it to predict possible vegetational coverages that may compete with planted or natural tree regeneration. Wildlife and range specialists might use FORSUM to compare the effect of alternative treatments on forage and browse species. Hydrologists might use it to decide if a certain treatment will promote the growth of species important for preventing excess soil erosion. Other potential uses include updating vegetation information in GIS (Geographic Information Systems) and demonstrating successional dynamics.

SUMMARY

The successional classification system of Arno and others (1985) provides land managers a means of classifying seral plant communities within a habitat type. The classification can also indicate the position of a community along a succession gradient. This allows the manager to reconstruct the successional history, and more importantly, to predict the successional future of a forest stand. In addition, the classification can be used as a qualitative tool to assess the impacts on the vegetation of various silvicultural treatments or wildfire.

The succession computer model FORSUM improves the predictive ability of the classification by quantifying changes in successional coverage of plant species as a function of treatment type and severity, predisturbance plant composition, and site factors. Using this model, the land manager can project successional shifts in species cover as a consequence of management action. FORSUM is widely available for use and it may soon be expanded to cover additional habitat types.

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PYRAMID MODELS FOR SUCCESSION CLASSIFICATION

Robert Steele

ABSTRACT: A concept for classifying seral vegetation using indicator species is discussed. Classification and studies of seral vegetation in six habitat types have resulted in some important implications for land managers. Shortcomings of this approach are also noted.

INTRODUCTION

Over the past two decades, habitat type classifications based on potential vegetation (associations) have been developed over much of the western U.S. This recognition of environment through vegetation has fostered an awareness of vegetation diversity, especially among resource managers. Land managers now recognize the need to foresee the changes in vegetation that may result from management activities. But to identify, study, and communicate these changes some form of classification is needed. Habitat type classifications focus on environmental differences affecting potential vegetation. They provide a logical framework for studying succession and occasionally infer successional relationships but offer no classification of seral vegetation.

To classify seral vegetation, I explored several approaches and eventually chose a system (Steele 1984) that uses Hironaka's "cone model" concept of succession (Huschle and Hironaka 1980). The cone model concept was most appealing because it allows one to develop both a systematic and natural classification system. A systematic approach is useful because it reduces subjectivity in classification design and anyone who understands the system can modify and extend the classification to new areas. Natural classification, as opposed to technical ones designed for a specific use, tends to maximize application and prediction capabilities. Habitat types are an example of natural classification and as their originators R. and J. Daubenmire (1968) pointed out, the most natural system is "one that allows the most predictions about a unit from a mere knowledge of its position in the system." Natural classifications are, of course, artificial in the sense of being created by humans.

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They seldom suit any one purpose ideally but are well suited for multipurpose application.

THE PYRAMID MODEL CONCEPT

Pyramid classification models reflect an elaboration of the cone-shaped succession model (Huschle and Hironaka 1980). The classifications are systematic because the same principles are always applied. The approach is natural because the plant species provide classification parameters through their seral characteristics. For example, consider the tree layer in a given habitat type. (Tree, shrub, and herbaceous layers are treated separately because disturbances such as grazing or logging may affect only one layer and these layers often involve different rates of succession.) In this example, the tree layer contains Abies grandis, Pseudotsuga menziesii, and Pinus ponderosa; each species is "well represented," which is arbitrarily defined as canopy cover of at least 5 percent. This would be an Abies grandis habitat type and only these three tree species would be capable of becoming well represented. From ecological knowledge of these species, derived mainly through field observation, we can diagram their relative successional amplitudes (fig. 1). Pinus ponderosa has the least amplitude because it can be replaced successional by both Pseudotsuga and Abies. Pseudotsuga can be replaced by Abies but not by Pinus. Although this entire sequence may not happen following each disturbance on a given site, the relative amplitudes have been established for classification purposes.

From a natural classification standpoint, these relative amplitudes have segmented the time gradient on a successional scale and each species serves as an indicator of a particular segment. For classification purposes, the best indicator species is the one that is well represented and has the least successional amplitude (for example, P1P0 in fig. 1). Once the time gradient is segmented in this fashion we complete the classification by linking each seral indicator species with the possible dominant species (most canopy cover) for that layer (fig. 2). The result is a series of binomial taxonomic units called layer types (fig. 3) each of which reflects a certain temporal-structural condition. The first element of the binomial is the seral indicator species, the second element is the dominant species. Each group of layer types having the same seral indicator is called a layer group.

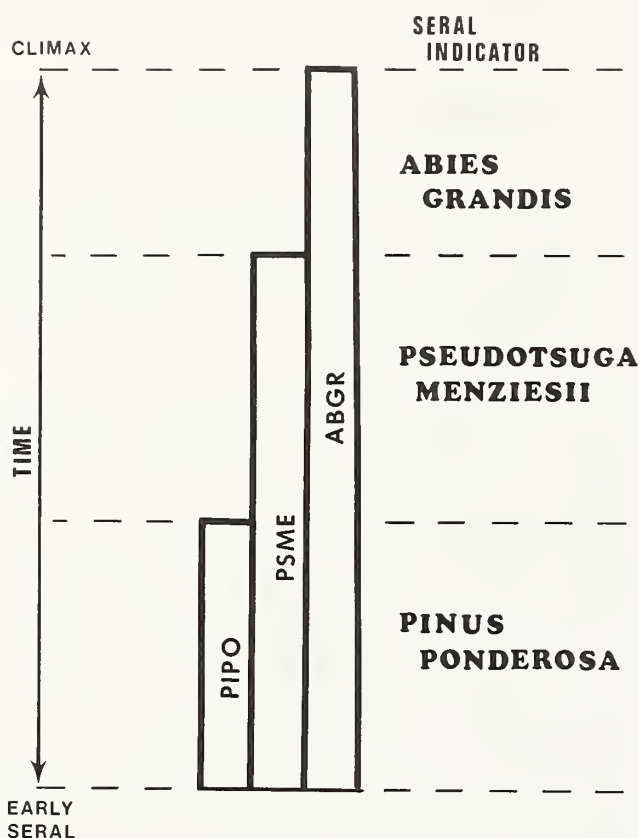


Figure 1--Example of relative successional amplitudes of tree species in a given habitat type.

This basic approach is used in the shrub and herbaceous layers but the tree layer progresses through obvious size classes of development such as sapling (0.1-4 inches d.b.h.), pole (4-12 in), mature (12-18 in), and old-growth (>18 in). These notations should be added to each tree species after the tree layer type is identified. For consistency, the smallest size class that is well represented should be noted for the seral indicator because it usually reflects the most recent regeneration of that species. For the dominant species, the most prevalent size class should be used. When the seral indicator or the dominant species is well represented on the site but not in any particular size class, the size class with the most coverage should be noted.

APPLICATION

This classification approach has been applied to the tree, shrub, and herbaceous layers of six habitat types in central Idaho (Steele and Geier-Hayes 1984, 1985, 1986, 1987a, 1987b, 1987c). The results show that a workable number of taxonomic units can be maintained in spite of high potential diversity. Many layer types occur across several habitat types and are

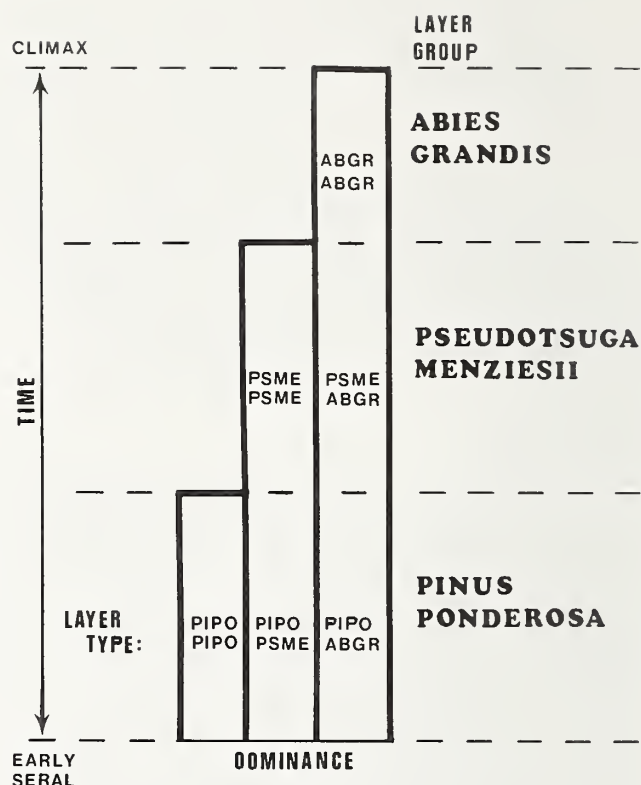


Figure 2--Example of possible seral indicator-dominant species combinations in a given habitat type.

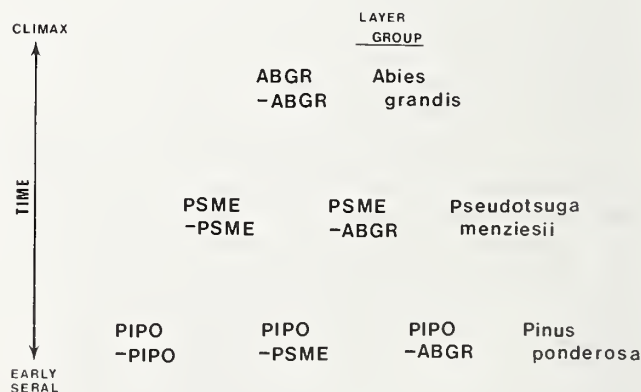


Figure 3--Example of succession classification diagram for the tree layer in a given habitat type.

easily recognized even though they may vary in total species composition. Some layer types result from only one kind of disturbance. Others can be achieved only through uninterrupted succession. Some of these layer types present special problems for achieving tree regeneration; others facilitate

regeneration. Some herb layer types support high pocket gopher activity, others support very little. Relative forage values for big game and livestock can be derived from species palatability ratings, constancy, and cover and also vary by shrub and herb layer type.

At present, most of the classifications cited above are available only in preliminary draft form. However, annual field training sessions have enabled land managers in central Idaho to use the results and their response has encouraged plans for similar work in other forest habitat types. Much interest has focused on the relationships between site treatment, the resulting shrub and herbaceous layer types, and the long-term effects on tree regeneration. Some interest has been expressed in using this classification approach in other geographic areas and in modeling rates of change within the pyramid models.

Developing these classifications involves many plant species yet relatively few serve as seral indicators. These indicator species appear to be consistent in their successional strategies across habitat types. But their successional role, whether early seral, mid seral, or climax is a function of associated species and varies by habitat type. In general, the successional role of a species shifts toward early seral in more favorable environments and toward climax in the less favorable environments. For instance, Pinus ponderosa may be early seral in Abies grandis habitat types, mid seral in Pseudotsuga habitat types, and climax in Pinus ponderosa habitat types. The extent of these shifts depends on which competitive species occur in the different environments. The implication of this for land managers is that plant species will generally establish more readily where they have major early seral roles than where they have late seral to climax roles. However, early seral species generally require special site preparation and are less apt to maintain their populations without repeated disturbance.

SHORTCOMINGS OF THIS SYSTEM

Like most systems, pyramid classification models have shortcomings. The system is based on species canopy cover and relative successional amplitudes. Canopy cover is not always proportional to canopy volume and total biomass can vary within layer types. Relative successional amplitudes for all seral indicators are not yet known, especially in the herb layer. Considerable field study is needed before pyramid models can be established for all seral vegetation in all habitat types. Existing pyramid models should always be open to further revision. Layer type designations are a function of only two species, seral indicator and dominant. Consequently, there can be high variability in total species composition within a layer type although usually this is not the case. Pyramid models do not predict what the next layer type will be for each stand within a given layer type. They only illustrate the successional possibilities that remain as well as situations no longer possible

unless disturbed. For individual stands, however, predicting the next layer type is possible by comparing total species composition of the stand with successional trends outlined in the pyramid models. For example, if a given stand contains a tree canopy cover of 10 percent PIPO, 40 percent PSME, and 20 percent ABGR, it will classify in figure 3 as a PIPO-PSME tree layer type. Once the pine has declined so that it is no longer well represented, the next layer type will most likely be PSME-PSME.

CONCLUSIONS

In spite of their shortcomings, pyramid classification models provide a systematic and natural approach to classifying seral vegetation. They were designed to provide a taxonomic framework for general field use but can be used to identify seral stages in simulation models. They also provide succession prediction capability for individual stands when the species composition is known.

Pyramid models accommodate the somewhat independent nature of succession between the tree, shrub, and herbaceous layers and treat these three successions separately. These models provide for the high potential diversity of early and mid-seral vegetation. Different kinds of disturbances can result in different shrub and herbaceous layer types which, in turn, affect pocket gopher populations and tree establishment. Shrub and herbaceous layer types can also be assigned forage resource values. Perhaps most important, these models provide a common framework for communication of seral plant communities among various resource disciplines.

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FORECASTING SECONDARY SUCCESSION WITH THE PROGNOSIS MODEL AND ITS EXTENSIONS

Melinda Moeur and Dennis E. Ferguson

ABSTRACT: The Prognosis Model for Stand Development predicts growth and development of individual trees in forest stands. The Regeneration Establishment and COVER extensions to the Prognosis Model have enhanced its ability to forecast secondary succession by predicting establishment of conifers and development of understory plants following stand disturbance. This paper discusses how secondary succession is predicted, emphasizing the role of habitat types in study design, data analysis, and model construction. Examples are given showing simulations for 40 years following harvest.

INTRODUCTION

The Prognosis Model (Stage 1973; Wykoff and others 1982) is usually thought of as a growth and yield simulator for forest stands. But the Prognosis Model and its extensions, Regeneration Establishment (ESTAB) and COVER, also incorporate successional concepts that enable it to realistically model changes in combinations of trees and understory plants through time. ESTAB predicts conifer regeneration following site disturbance (Ferguson and Crookston 1984). COVER (Moeur 1985) predicts tree canopy cover and biomass, and the probability of occurrence, height, and cover of shrubs, forbs, and grasses in the understory.

Biological characteristics of tree and understory species drive the models. The ecological potential of vegetation on different sites is incorporated into the models through the inclusion of habitat type and variables representing site conditions. An important part of our approach is that the models are derived from a large sample representing a wide range of site characteristics, stand structure, and silvicultural practices on the processes of vegetation change. Data to develop the models were measured on stands selected in a random, unbiased manner, covering a fairly complete range of stand and site conditions and regeneration activities likely to be encountered in application.

Using the combined Prognosis, ESTAB, and COVER models, tree and understory development may be simulated from rotation to rotation. This paper focuses on projections for the first 40 years

following harvest, showing the use of habitat types in modeling secondary succession.

The Prognosis Model

The Prognosis Model simulates stand development by predicting growth and mortality of individual trees sampled from an inventory. For each growth projection cycle (normally 10 years), the model predicts diameter and height growth, change in crown ratio, and mortality for each tree in the inventory (Wykoff and others 1982). In the Inland Empire version of Prognosis, growth relationships are included for 11 commercial conifer species. If harvest and site preparation activities are simulated, postharvest stand conditions stored by the Prognosis Model are passed to ESTAB and COVER to make predictions of secondary succession. Subsequent accretion, mortality, and user-implemented management prescriptions are handled by the main Prognosis Model.

The ESTAB Model

ESTAB predicts initial attributes of regenerating stands as they would appear if examined between 3 and 20 years after harvest and site preparation. Predictions include the probability of stocking for 1/300-acre plots, total trees per acre, species composition, identification of best trees, and heights of established seedlings.

Version 1.0 of ESTAB covers the grand fir-cedar-hemlock (Abies grandis-Thuja plicata-Tsuga heterophylla) ecosystem centered in northern Idaho (Ferguson and others 1986). Additional sampling has been conducted in Montana (Carlson and others 1982) and in Idaho (Ferguson and Stage 1982a) to include other vegetation types and geographic areas. These data are being used to extend ESTAB to Pseudotsuga menziesii and Abies lasiocarpa series and will be available in version 2.0.

In each study mentioned above, a stratified random sample was used to select operationally harvested stands 3 to 20 years old. Candidate stands were classified by habitat type, site preparation, regeneration method, and geographic location. Four or five stands within each combination were randomly chosen for sampling. Elevation, geographic location, dates of harvest, site preparation, and planting were recorded for each stand. Transect lines were drawn on aerial photographs and field crews sampled about 25 1/300-acre circular plots per stand along the transects. Information recorded by plot included habitat type, slope, aspect, type of site disturbance, topographic position, and overstory density by species. Conifer regeneration was counted by species, and

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height and age were subsampled on best trees on the plot. The total sample from which version 2.0 of ESTAB is being developed includes more than 12,000 1/300-acre plots from 537 stands.

The COVER Model

Two submodels within COVER predict the structure of tree crowns and understory vegetation. The CANOPY submodel predicts crown dimensions of individual trees, canopy closure, and foliage biomass of all conifers in the stand. Understory development is projected by the SHRUBS submodel for the initial 40 years following stand disturbance. Probability of occurrence on 1/300-acre plots, height, and percent cover are projected individually for each of 31 species or species groups common to northern Rocky Mountain forests.

Data used to develop the SHRUBS submodel were collected concurrently with the regeneration establishment studies by Ferguson and others (1986) and Ferguson and Stage (1982a) plus data from a regeneration development study (Deitschman and others 1974; Ferguson and Stage 1982b). The development study provided data for predicting 5-year periodic height growth of conifer regeneration in the same geographic areas as the regeneration establishment studies. These stands were selected to represent combinations of habitat type, regeneration method, geographic location, tree size, and tree species.

On both the regeneration establishment and development plots, average height and percentage of plot coverage were recorded by species for shrubs, forbs, ferns, and grasses on 1/300-acre plots, and density of the conifer overstory was measured on a variable radius plot. Data from all studies yielded 32,000 observations on 10,500 plots in over 500 stands.

HOW HABITAT TYPES ARE USED

Habitat types are the framework within which we have modeled conifer establishment and understory species occurrence and development. Habitat type incorporates many site characteristics and acts as an indicator of ecological potential in the models. In ESTAB and SHRUBS, habitat type accounts for much of the explainable variation in the data. The inclusion of other variables in the equations--slope, aspect, elevation, stand history, and overstory characteristics--improves predictions.

In ESTAB, habitat type is the second most important independent variable used to predict the probability of stocking on 1/300-acre plots (Ferguson and others 1986). The most important variable is time since disturbance, with 10 other variables being less important than habitat type.

In our secondary succession studies, habitat type, geographic area, site disturbance, and regeneration method were used to categorize stands so that combinations of events would be included in the sample. This stratification ensured coverage of most ecological conditions

likely to be encountered in forest management. Equally important is the use of habitat types in analyzing data and constructing models. Three examples follow.

Habitat Type Groups

Habitat types for version 1.0 of ESTAB used the classification system of Daubenmire and Daubenmire (1968). Version 2.0 uses systems of Pfister and others (1977) for Montana, Cooper and others (1987) for northern Idaho, and Steele and others (1981) for central Idaho.

For version 2.0 of ESTAB, habitat types were combined into 16 groups (table 1). Habitat types with nonsignificant differences between means for three variables (percentage of stocked plots, trees per stocked plot, and species per stocked plot) using Duncan's multiple range test ($p=0.05$) were combined within series. These variables correspond to important steps in ESTAB. Because the analysis did not account for differences in other site factors, the groupings were considered preliminary and were reviewed by area ecologists. Habitat types with limited data were combined with ecologically similar types.

In the SHRUBS submodel, 34 recorded habitat types were collapsed into groups to create two new variables--five habitat type overstory series representing climax tree species and six groups representing understory union (table 2). Analysis of covariance with time since disturbance as the covariate was used to reduce original understory unions to six classes (Laursen 1984). Temperature-moisture regime and number of shrub canopies and species supported in each union were used subjectively to make final adjustments in each grouping. Understory unions fell into one class of grass- and sedge-dominated communities, two classes representing low and mid shrub-dominated communities, and three classes typified by a high degree of potential structural diversity (tall, medium, and low species combined).

Species Occurrence

Species occurrence in ESTAB is very dependent on habitat type. Habitat types or groups are used as class (dummy) variables in regression equations so that each habitat type has a unique probability for the species being modeled. Ecological bar charts developed by Daubenmire (1966), shown in figure 1, detail the occurrence of species by climax series.

Species occurrences are used to partition data into logical units for analysis in ESTAB. For example, to predict the probability of occurrence of grand fir, only four series are analyzed--Abies grandis, Thuja plicata, Tsuga heterophylla, and Abies lasiocarpa. Plots falling in the Pinus ponderosa or Pseudotsuga menziesii series are excluded since the probability of grand fir occurring on such plots is nil. Even within a series, some habitat types do not support species found elsewhere in the series. These types can also be excluded from the analysis.

Table 1--Habitat type group for predicting conifer regeneration in the Regeneration Establishment Model. See table 3 for explanation of species codes

Habitat type group	Number of plots	Percent stocking	Trees/ stocked plot	Species/ stocked plot
1 PSME/VAGL,LIBO,VACA	296	59.1	3.49	1.36
2 PSME/CARU,CAGE,FEID, AGSP	417	29.5	2.99	1.21
3 PSME/PHMA,ACGL	832	25.4	2.31	1.14
4 PSME/SYAL,SPBE,SYOR, ARUV,ARCO,BERE	887	27.8	2.35	1.13
5 ABGR/LIBO,CLUN-XETE	273	79.5	5.06	1.81
6 ABGR/XETE,VAGL,COOC, VACA	451	45.7	3.22	1.48
7 ABGR/CLUN (except CLUN-XETE)	1,865	51.3	4.36	1.48
8 ABGR/SPBE,ACGL,PHMA, ASCA,SETR	989	37.3	2.53	1.28
9 THPL/all	2,180	61.1	9.53	1.74
10 TSHE/all	1,387	71.7	10.53	2.05
11 ABLA/VAGL,VASC,VACA	342	63.4	4.73	1.44
12 ABLA/XETE,LIBO	675	58.2	4.04	1.56
13 ABLA/CLUN,GATR	680	54.0	6.53	1.65
14 ABLA/CAGE,CARU,ACGL, SPBE	228	36.8	2.79	1.23
15 ABLA/MEFE, ALSI, and TSME/CLUN,XETE,MEFE, STAM	460	66.1	6.78	1.66
16 ABLA/CACA,STAM,LUHI	166	35.5	3.81	1.36
	12,128			

Table 2--Habitat type group used to predict probability of occurrence, height, and cover of understory species in the SHRUBS model. See table 3 for explanation of species codes

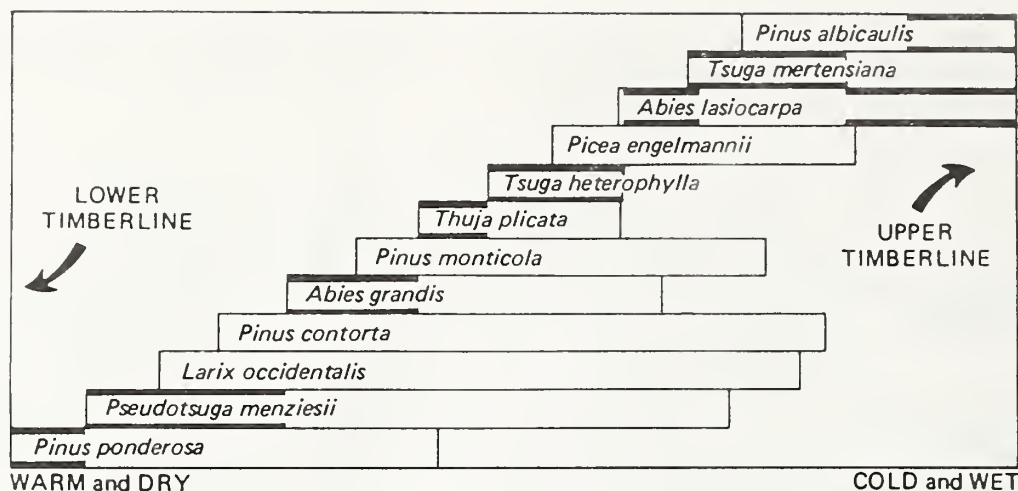
Overstory series groups	Number of plots
1 PSME/all	1,024
2 ABGR/all	3,311
3 THPL/all	2,649
4 TSHE/CLUN	2,041
5 ABLA/all and TSME/XETE	1,493
	10,518
Understory union groups	Number of plots
1 ABGR/CLUN,COOC,LIBO,XETE; TSME/XETE; ABLA/XETE,STAM,LUHI,VASC	2,743
2 PSME/PHMA,ACGL; ABGR/ACGL,VAGL; ABLA/ACGL,MEFE,VAGL,VAGL-VASC	1,332
3 THPL/all	2,649
4 PSME/SYAL,SYOR,SPBE,BERE; ABGR/SPBE; ABLA/SPBE	781
5 ABLA/CLUN; TSHE/CLUN	2,702
6 PSME/CARU,FEID,AGSP,CAGE; ABLA/CAGE, CACA	311
	10,518

Table 3--Abbreviations for scientific names

Code	Scientific name
ABGR	<u>Abies grandis</u>
ABLA	<u>Abies lasiocarpa</u>
ACGL	<u>Acer glabrum</u>
AGSP	<u>Agropyron spicatum</u>
ALSI	<u>Alnus sinuata</u>
ARCO	<u>Arnica cordifolia</u>
ARUV	<u>Arctostaphylos uva-ursi</u>
ASCA	<u>Asarum caudatum</u>
BERE	<u>Berberis repens</u>
CACA	<u>Calamagrostis canadensis</u>
CAGE	<u>Carex geyeri</u>
CARU	<u>Calamagrostis rubescens</u>
CLUN	<u>Clintonia uniflora</u>
COOC	<u>Coptis occidentalis</u>
FEID	<u>Festuca idahoensis</u>
GATR	<u>Galium triflorum</u>
LIBO	<u>Linnaea borealis</u>
LUHI	<u>Luzula hitchcockii</u>
MEFE	<u>Menziesia ferruginea</u>
PHMA	<u>Physocarpus malvaceus</u>
PSME	<u>Pseudotsuga menziesii</u>
SETR	<u>Senecio triangularis</u>
SPBE	<u>Spiraea betulifolia</u>
STAM	<u>Streptopus amplexifolius</u>
SYAL	<u>Symphoricarpos albus</u>
SYOR	<u>Symphoricarpos oreophilus</u>
THPL	<u>Thuja plicata</u>
TSHE	<u>Tsuga heterophylla</u>
TSME	<u>Tsuga mertensiana</u>
VACA	<u>Vaccinium caespitosum</u>
VAGL	<u>Vaccinium globulare</u>
VASC	<u>Vaccinium scoparium</u>
XETE	<u>Xerophyllum tenax</u>

In the understory models, probability of occurrence is related more strongly to habitat type than to other variables, representing restrictions in the ecological distribution of the species (Scharosch 1986). As examples, mesic understory species such as Vaccinium membranaceum have predicted probability of occurrence close to zero in habitat types having dry, grass-type understory unions, shifting to more consistent occurrence in moister habitat types (fig. 2); predicted occurrence of Physocarpus malvaceus is fairly well restricted to the Pseudotsuga menziesii/Physocarpus malvaceus association; and predicted occurrence of Symphoricarpos albus reflects published constancy values (Cooper and others 1987, for example).

Other important understory species' characteristics preserved in the predictions include patterns in early or late successional development, response to type of disturbance, and species' shade tolerance. In general, understory union is also a strong predictor of total shrub cover. Understory union integrates physical site characteristics, the number of understory canopies a site can support, and potential domination by particular species adapted to growth on a given site (Laursen 1984). Understory unions capable of supporting multiple shrub canopies (low, medium, and tall species) predict relatively higher total cover.



Coniferous trees in the area centered on eastern Washington and northern Idaho, arranged vertically to show the usual order in which the species are encountered with increasing altitude. The horizontal bars designate upper and lower limits of the species relative to the climatic gradient. That portion of a species' altitudinal range in which it can maintain a self-reproducing population in the face of intense competition is indicated by the heavy lines.

Figure 1--Ecological bar chart showing species occurrence by overstory series (modified from Daubenmire 1966. Copyright 1966 by the AAAS).

Optimum Aspect

Data can also be partitioned and tested for effects that differ among habitat types. For example, regeneration of Douglas-fir (*Pseudotsuga menziesii*), a species having a wide ecological amplitude, might differ among climax series. Daubenmire (1976) said

"... the *Pseudotsuga/Physocarpus* forest occurs on steep north-facing slopes at its lowest altitudinal limits, moves onto zonal soils at intermediate elevations, then onto the shallow soils of steep south-facing slopes at its highest limits." It follows that the best aspect for Douglas-fir regeneration might vary with climax series. We were able to test this hypothesis using data collected for version 2.0 of ESTAB.

PROBABILITY

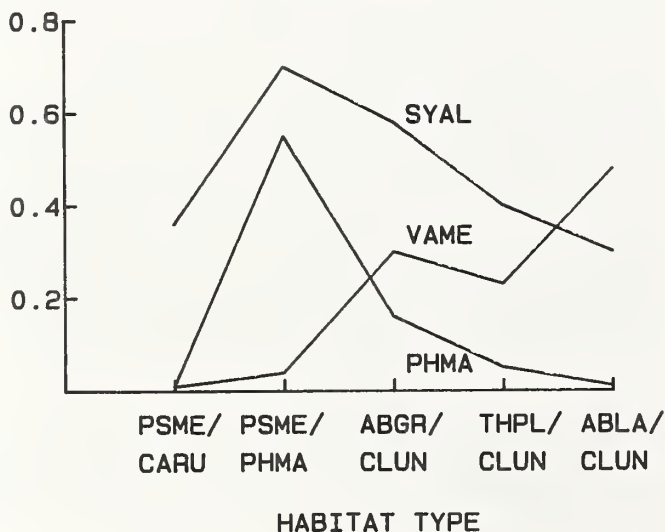


Figure 2--Occurrence of selected shrub species on habitat types as predicted by the SHRUBS model. Variables held constant: 30 percent slope, west aspect, no site preparation, 3,500 feet elevation, and 20 years since harvest. Although habitat types are not continuous, points on the graph have been connected to display trends in species occurrence.

Regression equations for the probability of subsequent Douglas-fir regeneration on stocked plots were developed by climax series--either *Pseudotsuga menziesii*, *Abies grandis*, *Thuja plicata*/*Tsuga heterophylla* together, or *Abies lasiocarpa*. Independent variables were slope, aspect, elevation, site preparation, time since disturbance, and residual basal area and species composition.

Results of these regression analyses support Daubenmire's statement. The optimum aspect in our model for Douglas-fir in the *Pseudotsuga menziesii* series is northerly (fig. 3). Aspects in the *Abies grandis* and *Thuja plicata*/*Tsuga heterophylla* series were nonsignificant (therefore not plotted) and the optimum aspect for Douglas-fir in the *Abies lasiocarpa* series is southerly. If habitat types were not used to partition the data, optimum aspect would be incorrectly predicted or aspect would have been insignificant and dropped from the equation.

Aspect is also a significant predictor of shrub species' occurrence. Figure 4 shows shrub predictions for *Pseudotsuga menziesii*/*Symphoricarpos albus* and *Abies lasiocarpa*/*Menziesia ferruginea* habitat types. *Symphoricarpos albus* and *Menziesia ferruginea* show opposite patterns in occurrence, with *Symphoricarpos* highest and *Menziesia* lowest on south aspects.

PROBABILITY

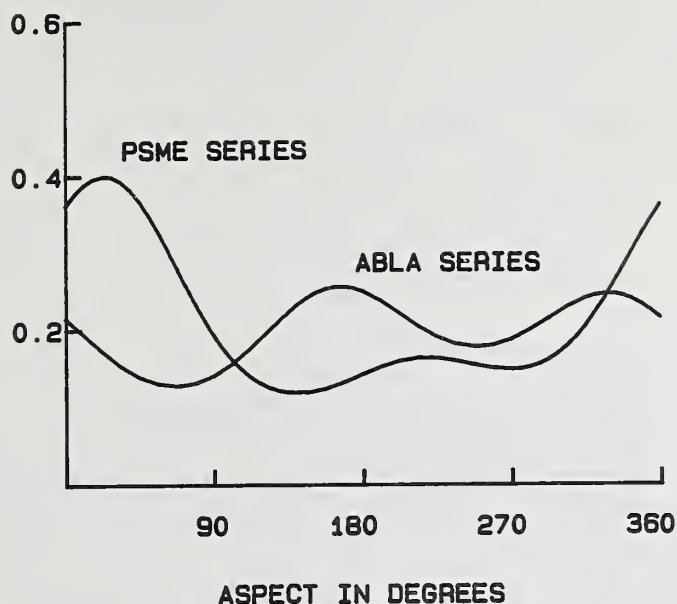


Figure 3--Probability of subsequent Douglas-fir regeneration by aspect for the Pseudotsuga menziesii and Abies lasiocarpa series. Variables held constant: 30 percent slope, no site preparation, 3,500 feet elevation, 20 years since harvest, and no overstory.

Other site variables influence the understory predictions. Greater understory development is predicted at low elevations and moderate to steep slopes. Overstory basal area and time since disturbance affect trends in species' height and cover development, and longevity. They explain more variation later in the successional sequence, reflecting species' sensitivity to overstory development. Type of disturbance influences the predictions by shifting height and cover values up or down reflecting species' adaptations to particular environments (Laursen 1984).

AN EXAMPLE PROJECTION

Four components of Prognosis drive predictions of secondary succession --the COVER and ESTAB extensions, and regeneration height growth and mortality equations in the main Prognosis model. Regeneration height growth equations are given by Wykoff and others (1982) and the mortality model is that of Hamilton (1986). All four components must work in harmony. An example will show results of exercising these models.

Two hypothetical stands were projected. They are similar except for habitat type. One stand is an Abies grandis/Pachistima myrsinites (ABGR/PAMY) habitat type and the other a Tsuga heterophylla/Pachistima myrsinites (TSHE/PAMY) habitat type (Daubenmire and Daubenmire 1968). Other attributes are south aspect, 30 percent slope, 3,500 feet elevation, no residual overstory, no site preparation, and the stands are located on the Clearwater

PROBABILITY

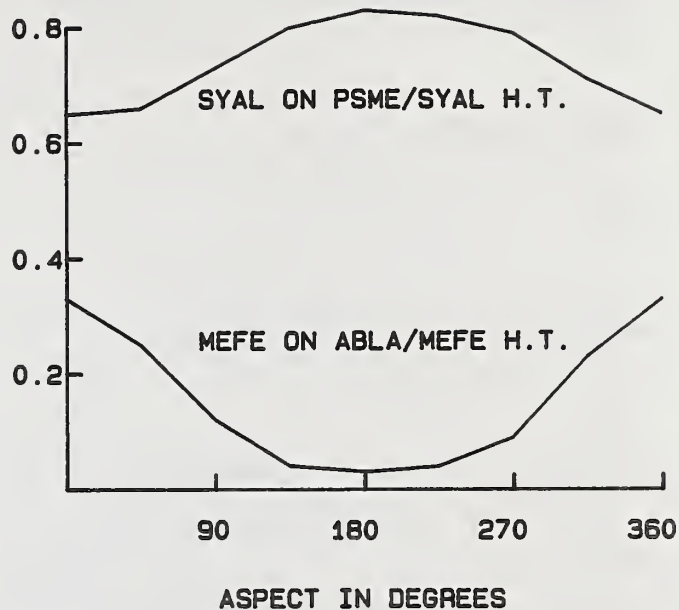


Figure 4--Probability of occurrence by aspect of Symphoricarpos albus on a Pseudotsuga menziesii/Symphoricarpos albus habitat type and Menziesia ferruginea on an Abies lasiocarpa/Menziesia ferruginea habitat type.

National Forest, ID. Projections were made with version 5.2 of the Prognosis Model.

Projected conifer regeneration in the TSHE/PAMY habitat type is more rapid and the density of trees is greater than in the ABGR/PAMY habitat type (fig. 5). After 20 years, 645 trees are predicted for the TSHE/PAMY stand and 263 for the ABGR/PAMY stand. The number of trees in both stands is low because of the steep, south aspect. Species composition in the ABGR/PAMY stand is mostly grand fir and Douglas-fir. The TSHE/PAMY stand regenerates well to western hemlock and western redcedar which, by definition, do not occur in the ABGR/PAMY habitat type.

Average height of the largest 40 trees per acre is higher for all time intervals in the TSHE/PAMY stand (fig. 6). Canopy closure progresses faster in the TSHE/PAMY stand (fig. 7), due to greater numbers of trees per acre and faster growth rates.

Total shrub cover is greater in the ABGR/PAMY stand (fig. 8). Shrub cover in the TSHE/PAMY stand is less and begins to drop sharply between stand age 30 and 40. This faster decrease is attributable to a faster progression toward canopy closure resulting from more trees per acre and faster growth rates in the TSHE/PAMY stand.

Predicted shrub species composition of the two stands was quite similar. Tall shrubs consisted of Acer glabrum, Amelanchier alnifolia, Ceanothus velutinus, Salix spp., and Cornus stolonifera. Medium shrubs common to both stands were Rubus parviflorus and Vaccinium membranaceum. The ABGR/PAMY stand had a

good deal of Symphoricarpos albus while the TSHE/PAMY stand had little. Both stands had the same low shrub species--Pachistima myrsinites, Spiraea betulifolia, and Linnaea borealis.

DISCUSSION

Succession modeling in the COVER and ESTAB models deals with the early, formative years in the life of a stand. Stand dynamics are rapid, setting the

TREES PER ACRE

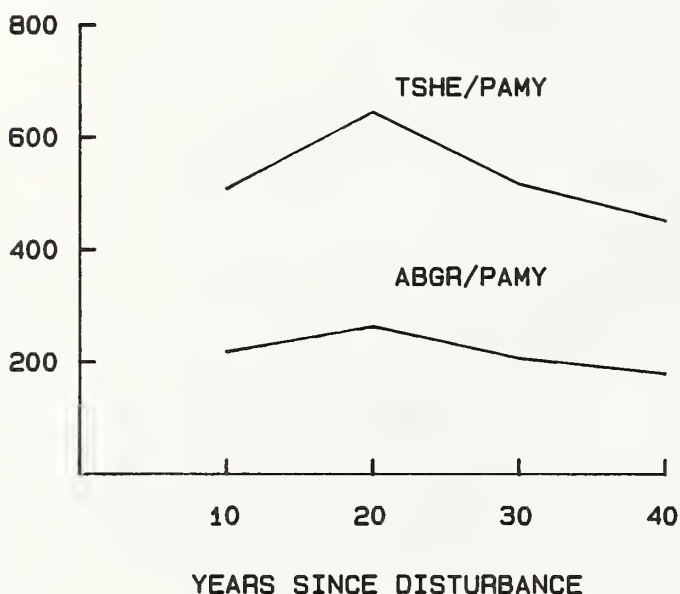


Figure 5--Predicted trees per acre by habitat type.

CANOPY CLOSURE (%)

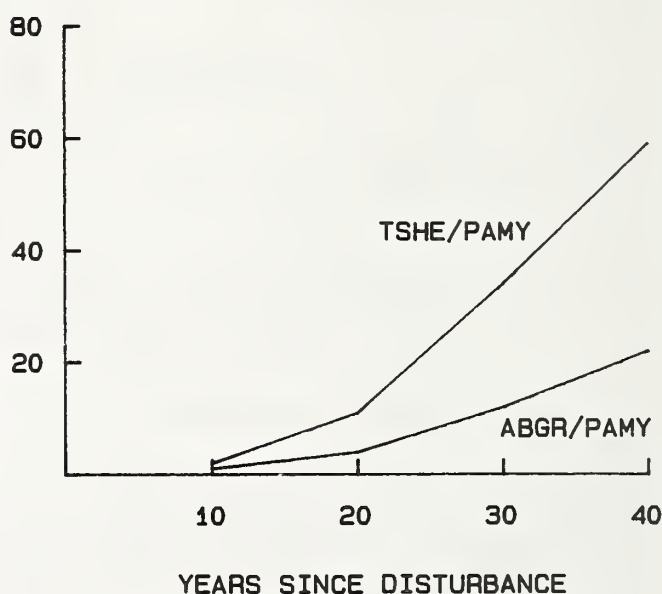


Figure 7.--Predicted conifer canopy closure by habitat type.

TOP HEIGHT (FT)

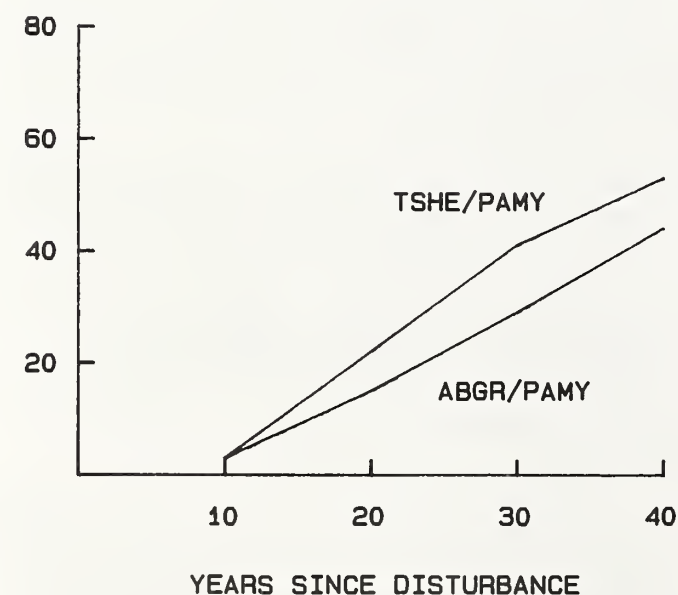


Figure 6--Predicted conifer top height by habitat type.

SHRUB COVER (%)

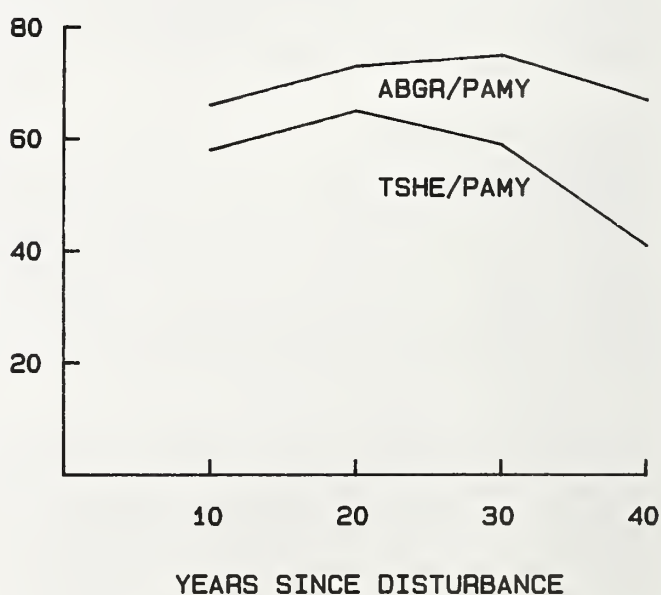


Figure 8--Predicted shrub cover by habitat type.

stage for the remainder of the rotation. Silvicultural prescriptions, beginning with the regeneration method and followed by site preparation, planting, and pest control, are accomplished at this time.

In modeling secondary succession we have chosen to measure and include in the predictive models certain biological and environmental variables that are clearly related to conifer seedling establishment and shrub response to disturbance. The concept behind this is simple: succession, while an extremely variable process, is not a random process. If it were random, the model predictions would be no better than chance. Clearly, habitat types play an important role in representing successional trends in the model.

One unique aspect of COVER and ESTAB is that they incorporate the effects of numerous site and stand history variables--habitat type, aspect, slope, elevation, overstory density, and disturbance history--which have not often been considered in other studies. The resulting equations provide generally well-behaved, biologically reasonable predictions that explain much of the inherent variability in post-disturbance communities.

We believe combining theoretical concepts of species ecologies with a statistically based relationship drawn from a large sample is a good way to represent successional trends over a wide range of site and management conditions, especially in the context of a stand simulation model. For best inferences of succession on a particular site, this approach combined with pre-disturbance sampling of initial floristics, may give excellent results.

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SUCCESSION MODELING AND WILDLIFE HABITAT MANAGEMENT

L. Jack Lyon

ABSTRACT: Successional theory has had little impact on the practice of wildlife management except possibly as a means of predicting success in habitat manipulation. In recent years, however, evaluating habitat quality and predicting the future have become important parts of planning. Using computers, we have constructed wildlife habitat models to examine and evaluate forest environments and forest succession models to predict growth and structure of plant communities. We have paid surprisingly little attention to the quality of these models. Wildlife models produce scalar values rather than numbers, depend on concepts of sometimes questionable validity, are limited by hidden or unstated assumptions, and stray with some regularity from biologically meaningful assessment. Succession models lack a strong basic concept, are too general or too specific, and often provide the wrong kind of information. We probably should remember that predictions of changes in wildlife populations over time are only as good as the habitat models and succession models used to make predictions.

INTRODUCTION

Succession is "...one of the oldest shared research commitments in ecology..." (Johnson 1979). Succession science, if such a science exists, has a large body of theory dating back to 1859, but management applications in some fields still seem to be floundering. Applications to wildlife management, in particular, have evaded development beyond what many biologists consider completely obvious wildlife management theory. Wildlife habitats change over time, and as a consequence, so do wildlife populations. When habitat changes occur as natural events, we call them succession. When the changes result from management action, we like to call it habitat manipulation. Either way, positive and predictable benefits for wildlife are as often the result of serendipity as of good intentions. We recognize that habitat changes are occurring, we may even cause those changes, but no one quite seems to know what to do about them.

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There are probably several good reasons succession theory has not become an integral part of wildlife management. It is difficult, for example, to deal with the concept of succession when even the experts in the field cannot decide what it is, or how to describe it. Today, in this session, you have heard four different versions of the way succession can be described. Even a brief review of the historically important literature will reveal the theoretical disagreements of Clements and Gleason and the quantum changes in viewpoint represented in the writings of Odum, and more recently West, Shugart, and Botkin (West and others 1981). However, the fact that the causal relationships of succession have not been described with scientific rigor should not be considered limiting. Quite a lot of wildlife management lacks scientific rigor.

A secondary reason succession theory is not integral to wildlife management involves the view that vegetation science is peripheral to everyday wildlife management. For many game species, management consists of annual surveys, hunting season reports, and even wishful thinking to provide information on which decisions can be made. The required data collection and decisions are made in a short time frame, uninfluenced by succession.

Planned habitat manipulation brings wildlife management and succession into a slightly closer relationship, but the manager may still consider the growth of vegetation a peripheral concern. Blasting an open water pond in a cattail marsh clearly provides more action than watching the grass grow on a burned winter range. When measurable responses in numbers of animals take more than a few years, the level of excitement does not reach great peaks.

Evaluation of wildlife habitats probably represents the closest relationship between management and succession because successional communities often provide the categories of analysis. Again, however, this wildlife management task is usually done on a short time frame, uninfluenced by successional changes. Predictions of successional change should be a standard part of the evaluation analysis, but such predictions are very rarely completed.

In recent years, the importance of succession to changes in wildlife habitats and wildlife populations has become more widely recognized because so much effort is going into planning. The development of National Forest plans, in particular, has emphasized both short-term and

long-term influences of timber harvest on the forest environment and on forest wildlife populations. Wildlife managers are still uncertain about the future, but at least an action framework has been established, and some recent developments represent exciting new theory.

The current framework for integrating successional knowledge into wildlife habitat management involves two basic concepts: (1) that the quality of existing and future wildlife habitats can be evaluated, and (2) that successional information is adequate to allow prediction of form and structure in future wildlife habitats. In the remainder of this paper I consider the thesis that neither of these concepts currently provides a foundation worthy of the massive structure being built.

ASSESSING HABITAT QUALITY

Aldo Leopold (1933) described "game range," for any wildlife species, as a place where food and cover are found in appropriate juxtaposition. Today such places are called "wildlife habitats" rather than game ranges, but in over 50 years there has been no particular improvement in the definition. And, while our ability to measure and describe the characteristics of wildlife habitats appears to have become more sophisticated in those 50 years, it is not clear that the results are any more accurate. We have taken computers and created a complex system of models that claims to evaluate habitat quality, but our answers take the form of esoteric and parochial value scales of habitat quality with only presumptive relationships to actual or potential animal numbers and population characteristics.

Is output of real numbers an impossible goal? If we examine some recent wildlife habitat research and the direction current research seems to be heading, it does not appear impossible. Only 4 years ago there was enough interest in wildlife habitat modeling to justify the international symposium, Wildlife 2000, and the compilation of nearly 80 papers (Verner and others 1986) describing recent work in this area. It was a disappointment that a substantial proportion of those papers demonstrated the failure of models to yield accurate predictions. At the same time, the printed proceedings provide many incentives for the development of better models. One of the most pressing is that models will be used even when we recognize that such use "...is not controlled by scientific veracity, though one would like to have the most accurate models affordable" (Salwasser 1986: 423).

Wildlife Habitat Models

Models intended to describe wildlife habitat have taken a wide variety of forms, from simple linear and curvilinear regression equations to complex multiple regressions and even more complex modifications involving geographic

information systems (GIS). Berry (1986) provided a brief overview of modeling for the Wildlife 2000 Symposium, and left little doubt that models and modeling systems proliferate, and create new acronyms, at a much higher rate than tests of model validity.

The Fish and Wildlife Service, the Forest Service, and the Bureau of Land Management have been busily creating HSI (Habitat Suitability Index), PATREC (Pattern Recognition), HC (Habitat Capability), IHICS (Integrated Habitat Inventory and Classification Systems), WFHR (Wildlife and Fish Habitat Relationships), and HEP (Habitat Evaluation Procedures) models almost without pause. Most are single-species models, others supposedly represent communities. Agency loyalty demands a certain amount of missionary defense of your own personal acronym, but there are few real differences in the underlying concepts or in the eventual output.

The primary differences among models lie in the assumptions required to produce each model and the problems created by those assumptions. Rather than discuss relatively minor differences among methods and models, I would like to briefly describe the basic concepts, some assumptions derived from those concepts, a few of the problems created by these assumptions, and some directions required to reach a solution.

Concepts

The underlying concepts in virtually all wildlife habitat models are straight out of Leopold's (1933) "Game Management." Schamberger and O'Neil (1986) suggested the defining concepts for HSI models are habitat (food and cover) and carrying capacity (usually expressed as a function of limiting factors). Starting with these concepts, it seems reasonable to propose that wildlife populations levels are determined by the quality of habitat and to conclude that appropriate measures of habitat quality will express potential carrying capacity. Such a conclusion, however, is a quantum jump requiring substantial oversimplification of complex systems at great cost in resolution. Habitat and carrying capacity, as concepts, are far easier to understand when they do not have to be expressed numerically.

Assumptions

Reducing concepts to numbers causes oversimplification because it is usually possible to include only a few factors of environment in a model. Selecting the appropriate factors requires some assumptions about the parameters of major importance and the ways those parameters influence animals. To indicate the difficulty in making a good assumption, I will examine two essentially generic models in a very superficial way: the elk coordination model and the grizzly bear cumulative effects model.

Most models of elk habitat in the Northern Rockies and the Pacific Northwest (for example, Leege 1984; Thomas and others 1979; Wisdom and others 1986) are basically similar. To a greater or lesser degree, all have been developed from the same habitat and carrying capacity assumptions:

1. Elk habitat quality is a function of cover and forage;

2. Carrying capacity of elk habitat is limited by roads.

It is important to recognize, in this and other wildlife models, that these larger assumptions very often mask specific, but hidden, assumptions produced by parameter definitions. In the elk model, thermal cover for elk is defined as a stand of conifers 40 feet tall with canopy closure over 70 percent, while hiding cover is defined as vegetation obstructing observation of 90 percent of an elk at 200 feet. Any stand not classified as cover is a foraging area (Thomas and others 1979).

Whether inadvertently, or by intent, these definitions effectively remove forage as a variable in the model. At the same time, they force acceptance of two invalid assumptions: (1) that a forest stand with less than 90 percent hiding cover throughout has no hiding cover value, and (2) that a forest stand with less than 70 percent crown canopy closure has marginal thermal cover value.

The carrying capacity assumption in the elk model is based on numerous replicated samples of data showing that elk avoid open roads. The fact that they cannot as effectively utilize habitat adjacent to roads (Lyon 1983) becomes the implicit, but partially hidden, assumption that loss of habitat effectiveness is harmful to the health of an elk population.

An identical masking of assumptions can be seen in the grizzly bear Cumulative Effects Model (CEM) (Yellowstone Ecosystem). Although a much larger and more complex construction than any of the elk models, the CEM was also initiated with a habitat assumption and a carrying capacity assumption (Weaver and others 1986):

1. Area habitat quality is substantially a function of cover and food availability;

2. Disturbance determines the ability of a bear to use a specific habitat.

The definition for habitat in the CEM was developed from coefficients derived in analysis of a large data base describing scats, feeding sites, and seasonal food values (Mattson and others 1986). Within the model, edge density, seasonal equity, and protein concentrations provide additional subjective adjustments to calculated coefficients.

One hidden assumption, the emphasis on food values in the derivation of these coefficients, probably removes cover as a variable in the model. However, cover is restored as a part of

the carrying capacity assumption where hiding cover is defined as vegetation hiding 90 percent of a bear at 200 feet; different disturbance coefficients are assigned in cover and noncover situations. Again, but only by implication, there are hidden assumptions that a stand with less than 90 percent hiding cover has no hiding cover value, and that losses of habitat effectiveness are damaging to the health of a bear population.

Problems

Critics of wildlife habitat modeling will see in the preceding discussion strong evidence of fatal flaws. No evidence, however, has so far indicated that either of these models is wrong. Both may, in fact, provide exactly correct answers as long as the right questions are being asked. Schamberger and O'Neil (1986) emphasized that these are "...practical, operational planning models; designed to assess impacts of change; and based on a narrow definition of both habitat and carrying capacity." They should not be considered "...research models, carrying capacity models, population predictors,..."; or a host of other things they are not.

If there is a fatal flaw in wildlife habitat modeling, it will almost certainly be found in the restricted operational definitions of habitat and carrying capacity. However, the restricted definitions are not the real problem, they simply represent clear evidence that the kinds of information utilized to build habitat models are probably inadequate and may be of the wrong kind.

One of the flaws most often emphasized is the question whether data describing habitat selections by free-ranging animals indicate preferences instead of providing valid recognition of conditions required for survival. Why this should even be considered important is not clear to me. Like many biologists, I can see no positive value in identifying the absolute minimum of habitat conditions required to prevent local extinction.

However, the question is not totally ridiculous. It could produce a positive change in the research designs we use for identifying habitat parameters. Except for localized application, animal preference for a specific habitat condition is not the relevant question. If habitat models are to function with accuracy, they must be built on data derived from studies of specific daily stress, physiological or behavioral requirements, and responses of animals to identified stress conditions. If we knew what the habitat was providing for the animal, preference would not enter the picture. More important, alternative habitat structures that provide the same thing could be identified and extrapolation through modeling would become an important management tool.

A second flaw in habitat models is that carrying capacity assumptions always presume changes in

the habitat will produce changes in wildlife populations. Disregarding the awesome power of Murphy's Law, there are several other ways for this assumption to prove invalid. Random variations in the weather can reverse almost any prediction. For most game animals, negative changes in habitat quality are likely to produce increased management restrictions to maintain the same wildlife population in a poorer habitat. And, finally, many of the wildlife species of greatest interest are extremely adaptable to environmental change.

The greatest potential for a fatal flaw in habitat modeling lies in the short, logical step to the assumption that models are real. This step, unfortunately, cannot be prevented if the models are to serve any useful purpose. Nevertheless, it supplies a further reason for making every effort to improve the quality of models to a level that will provide accurate, if not precise, numerical representations of the real world.

Solutions

There is little question that models of wildlife habitat can provide the means of evaluating existing and future wildlife habitats. Not every model will be successful, however, and in the degree it is possible to do so, wildlife habitat models must be "validated." I use this term in the sense defined by Shugart and West (1980): "...testing does not make models 'valid'; it simply gives one an idea about the reliability and, hence, the utility of a given model."

Unfortunately, a number of realities weigh heavily against any large-scale validation efforts. Wildlife habitat models can be created at a greater rate than they can be tested, and few scientists believe that sound research can be conducted at the experimental level required by most models. Validation, particularly over a large region, requires far better wildlife census techniques than are currently available for the majority of species.

Some investigators have suggested that it may be more logical to approach validation of wildlife habitat models through comprehensive testing of the underlying assumptions. To this end, I would further suggest that models should only be constructed on assumptions framed so that (1) no hidden assumptions are inadvertently created, and (2) each assumption is itself a testable hypothesis. It is not essential that every assumption be tested, but it is essential that assumptions be clearly stated and that they represent relationships with meaningful biological explanations.

ADEQUACY OF SUCCESSIONAL INFORMATION

According to Johnson (1979: 238), ecologists have been attempting to define the concepts of succession for nearly 130 years. The period

before 1900 was "...formative, during which most of the architecture of the theory was laid out. This was followed by a developmental...period [1900-1930] dominated by Clements and Cowles, [and]...a radically different view...in the ideas of Gleason...." Johnson considers the period 1930 to 1947 a scholastic interval, presumably a period in which previous writings were studied and evaluated. After 1947, Johnson continues, "...there was a major loss of faith in the traditional ideas of succession." The result "...is the confused period in which we still find ourselves."

Johnson predicted the development of a new view of community dynamics profoundly different than succession, but the evidence from the short decade since his prediction is that we are still working our way through the "confused period." Descriptions of community dynamics have become more significant in the ecological literature of recent years. Whether they provide a profoundly different view of succession is open to interpretation. Most of our apparent progress seems to have been made in the development of larger and more sophisticated computer models rather than in major modifications of successional concepts.

Succession Models

There are, in fact, computerized succession models in mind-boggling profusion. Shugart and West (1980) reviewed more than three dozen forest dynamics models and classified 19 of them as forest succession models. A symposium on forest succession and stand development held in 1981 (Means 1982) contained 18 papers--more than half of which mentioned some kind of computer model. A quick review of the Wildlife 2000 Symposium (Verner and others 1986) shows attempts to link wildlife models with PROGNOSIS, DYNAST, FORPLAN, ECOSYM, HABSIM, TWIGS, FORHAB, SAMM, and several other models. The symposium this week will provide three to five additional models at either a conceptual or functional level.

However, while there is no shortage of models designed to predict succession, the wildlife manager might still ask what it is that is being predicted and whether the predictions have any basis in reality. Even more important, the manager might ask whether these models predict anything of value to wildlife. These are not questions that can be answered unequivocally, but the answers will not do much to increase your confidence.

Utility of Models

Accuracy and potential for extrapolation are extremely limited in most succession models. Just as wildlife habitat models are restricted by their assumptions, succession models are restricted by a lack of consistency in basic theory. One result, noted by Henderson (1982: 80), is that "The literature abounds with descriptive studies of succession. Yet when one

wishes to investigate a particular area or series, it becomes readily apparent that hard data are inadequate...." Franklin (1982: 167) proposed "...that successional theory developed solely from study of one ecosystem is almost invariably going to be a special case, inapplicable in detail, to another ecosystem." His solution was a general statement in which ecosystem change is described as a function of species life histories, environment, and stochastic variation. He noted that the formula is so general "...it could well bring despair to ecologists."

It is clearly a "no win" situation when existing data are too specific and a model of general application will produce widespread despair. And this is not the only problem. Succession models are almost always faulted for dealing with the wrong information in a way that is only indirectly applicable to the question at hand. Smith (1982) remarked: "It is an occupational disease of silviculturists to deal with the regeneration stages more than the final ones, of ecologists to deal mostly with the late stages, and of each group to fail to consider the whole process adequately."

Probably the major failing of existing models as related to applications in wildlife management is the tendency to treat trees as the only component of the forest community. Shugart and West (1980) classified their sample as tree models, gap models, or forest models on the basis of the way tree development was represented. In no case was the early seral development of understory vegetation considered. Other authors have noted a tendency for succession to focus on trees (Pfister 1982; Zamora 1982), sometimes even to the point of suggesting that succession starts at 4 inches d.b.h.

If wildlife management requires succession models with a little more sophistication than 4 inches d.b.h., wildlife managers will have to specify what is required. In general, this has not been done because the required specifications must come out of properly designed wildlife habitat models.

Solutions

Whatever their faults, forest succession models can usually be validated, or tested for reliability, because the vegetation being predicted will stand still for adequate census. Nevertheless, succession models, like wildlife models, can be created at a greater rate than they can be tested, and nonselective validation will certainly absorb more resources than are readily available for this purpose. Until we resolve the inability of succession models to handle some limited geographic extrapolation, along with the required array of areas, seres, species, and treatments, the proliferation of models is certain to exceed the potential for validation.

These realities have not, so far, resulted in the necessary restructuring of succession theory

to accommodate known variation. And, as long as computer storage capabilities can be expanded, it may not be necessary to develop a better theory at all. Some investigators have already decided to take a pragmatic approach to succession modeling through comprehensive storage of vast data collections. At this point, I find it hard to disagree. It may be more intellectually stimulating to develop and modify a new succession theory, but current progress in solving practical land management problems is taking place in the computer.

DISCUSSION AND CONCLUSIONS

Succession and wildlife management, along with many other visible phases of wildland management, appear to have succumbed to a computer revolution. Whether that produces applause or gnashing of teeth should be of little concern if the people in charge of the computers do not abrogate their responsibility. Wildlife habitat models can examine and evaluate forest environments with greater precision and at far greater speed than ever before. Forest succession models can predict growth and structure of plant communities more accurately and with greater speed than ever before. Combinations of these models have a potential for predicting with virtual certainty landscape structure and wildlife carrying capacity into the foreseeable future. The ability to make such predictions is a driving variable in planning and an almost daily justification for management action. With so much riding on the outcome, we are surprisingly overconfident about the quality of these models.

It is my conclusion that we should be asking a few more and a lot harder questions. We have wildlife models that produce scalar values rather than numbers, that depend on concepts of sometimes questionable validity, that are limited by hidden or unstated assumptions, and that stray with some regularity from biologically meaningful assessment. We have succession models that lack a strong basic concept, that are too general to be useful or too specific to have meaning, and that either way provide the wrong kind of information.

It is entirely possible we will one day create a kind of Computer Nirvana in which input of real data to accurate models of wildlife habitat and forest succession will output precise estimates of habitat structure and animal numbers over any acceptable time period. Meanwhile, we probably should remember that predictions of changes in wildlife populations over time are only as good as the habitat models and the models predicting succession.

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USING VEGETATION CLASSIFICATIONS TO GUIDE FIRE MANAGEMENT

Stephen F. Arno and William C. Fischer

ABSTRACT: The advent of "fire management" has increased the need to understand and predict fire effects on vegetation. Such prediction is greatly complicated by the many factors that influence fire characteristics and plant response. Nevertheless, a few approaches have been developed to synthesize fire effects information by vegetation types. These include hypothesized models of postfire succession for groups of habitat types and more detailed classifications of successional communities and pathways within some individual habitat types. This predictive information is used to set realistic goals for use of prescribed fire in forest planning and to preplan fire suppression under different scenarios for diverse areas of forest land.

INTRODUCTION

For thousands of years fire has been the principal initiator of succession in northern Rocky Mountain forests (Habeck and Mutch 1973; Mehrlinger 1985; Mehrlinger and others 1977). Since the late 1800's, however, Euroamerican settlement and land-use practices have altered the occurrence and role of fire in this region. A primary mission of Federal forestry in the western United States at the beginning of the 20th century was to suppress fire, which was viewed almost entirely as a destructive and unnecessary agent (Pyne 1982).

By the mid 1900's, many ecologists and foresters had noted that undesirable successional changes, fuel accumulations, and threats to tree vigor accompanied a lack of fire in some of the forest and range types (LeBarron 1957; Pyne 1982; Weaver 1943). Evidence of the necessity of returning fire in some form to many of these ecosystems continued to mount. In the 1970's the U.S. Department of Agriculture, Forest Service, the U.S. Department of the Interior, National Park Service, and other agencies recognized this need by transforming the fire suppression policy into a much broader policy called "fire management." This new policy includes suppression of unwanted

fires, but also attempts to return fire as a process to the wildlands (Fischer 1980; Kilgore 1983; Nelson 1979). In wilderness as well as in commercial forests, "prescribed fire" will be used. This is defined as fire burning under conditions that were planned ahead of time to accomplish desired effects (Fischer 1978; Martin and Dell 1978).

The advent of fire management has brought about a great need to understand and predict fire effects on vegetation. Meeting this need is complicated by the fact that fire is a variable treatment, ranging from light burning in the forest understory that causes minimal mortality to spectacular crown fires that can kill the tree layer over large areas during the course of a few hours. Furthermore, an individual fire often burns at different severities leaving a mosaic of treatments on the landscape.

The principal factors affecting the kind of fire treatment that occurs on a given site include weather conditions, fuel moisture, topography, and the successional stage of vegetation. This latter factor involves vegetation's role as fuel. Fire may spread primarily through dead vegetation such as litter and duff, downed woody material, and cured grasses and forbs. Additionally, living vegetation such as understory conifers can serve as a fuel ladder that allows torching into the overstory. If surface fuels are adequate, a dense tree layer can support a running crown fire.

Fuel loadings, fire behavior, and fire effects are strongly influenced by characteristics of the vegetation, including its productivity, decay rate, community structure, and flammability. These characteristics are directly related to the successional community type and indirectly linked to the site or potential vegetation type. Effects of fire are heavily influenced by fire-resistance and regeneration mechanisms of tree and undergrowth species.

MODELING FIRE EFFECTS

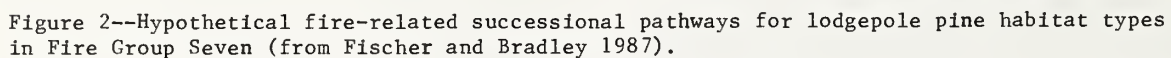
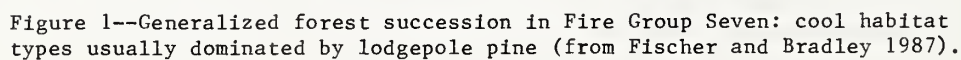
The effects of different fire treatments within a given habitat type have been predicted by modeling the effects of fire on the principal species of trees and undergrowth plants. This is done using a "selected attributes-multiple pathways model" based on life-history characteristics of each species (Connell and Slatyer 1977; Noble and Slatyer 1977). This conceptual approach for portraying postfire succession was initially applied to fire management planning in Glacier National Park and the Lewis and Clark National

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Since 1980, Fischer and several co-authors have expanded the application of selected attributes-multiple pathways models to characterize postfire succession in groups of "habitat types," site types based on potential vegetation (Crane and Fischer 1986; Fischer and Bradley 1987; Fischer and Clayton 1983; Kessell and Fischer 1981). The forest habitat types of Montana (Pfister and others 1977) were placed into

Simple models depict hypothesized successional pathways for each fire group (fig. 1 and 2). The



major structural stages are shown--for example, herbaceous community, a shrubfield, and various tree stages--and the differences in dominant tree species are indicated. The models also depict the common successional pathways that result from imposing fires of different severities on each structural stage (fig. 2).

FIRE GROUP USES

Habitat types serve as a principal element of land stratification for forest plans on the National Forests. Fire groups have been used as a means to integrate fire considerations in forest plans (Stiger 1980). They are also used as a basis for ranger district and National Forest fire management plans (Davis 1978, 1979b). For example, National Forest fire management plans include a decision process for determining the appropriate response to any unplanned ignition that might occur. This planned response to fire assesses the resource, property, and social values at risk on each site. The probable responses of these values to a given fire are predicted, including the likely spread of the fire into areas having other values at risk. This presuppression planning employs the fire ecology information presented by habitat type groups in designing cost-effective strategies for dealing with each fire. It may be classified as a wildfire and confined, contained, or suppressed; or it may be declared a prescribed fire and allowed to burn.

Appropriate uses of prescribed fire to accomplish certain resource management objectives are presented for each habitat type group. These fire-use considerations include recommended frequencies of burning, procedures for hazard reduction, forage production, site preparation, stocking control, and recreation site maintenance (Fischer and Bradley 1987). On some National Forest ranger districts, fire groups are also used to stratify information and data collected in evaluating the effects of prescribed fires.

Wilderness fire management planners have used fire groups in conjunction with land types to relate potential fire behavior and fire effects to specific areas of land (USDA Forest Service 1981, 1983). This has provided the documentation necessary to begin the process of returning fire to its role as a natural occurrence in wilderness. For example, fire groups provide a basis for assessing the natural role of fire in maintaining mosaics of successional communities within wilderness (Davis 1979a; Holdorf and others 1980; Royce and others 1979). Fire groups and cover types have been used as categories for summarizing data on surface fuel loadings and predicted fire behavior in northern Rocky Mountain forests (Brown and Bevins 1986; Brown and See 1981).

Fire groups have been published for the forest habitat types of Montana (Fischer and Bradley 1987; Fischer and Clayton 1983) and central Idaho (Crane and Fischer 1986). Fischer and co-authors are currently developing fire groups for the forest habitat types of National Forests in the

Rocky Mountain Region--Colorado, Wyoming, and South Dakota (review draft manuscript completed) and for forest habitat types of Utah (review draft estimated for June 1988).

SUCCESSIONAL CLASSIFICATIONS

Successional classifications for individual habitat types have been developed for a few of the major types in western Montana and central Idaho. These classifications provide detailed insight for predicting the effects of wildfire and silvicultural applications of fire. The classifications are based on a large number of sample stands in each habitat type. Most of the "treated" stands were burned by stand-replacing wildfire, clearcut and broadcast burned, or dozer-piled and burned. Adjacent "untreated" stands on the same site were sampled when available, to represent a "control."

The classification approach developed in western Montana and being used in the Northern Region of the Forest Service could be considered a simple extension of habitat type classification (Arno and others 1985, 1986; Keane 1987, this proceedings). In this approach, a habitat type phase is subdivided into "structural stages" and into compositional "community types" based on synthesis of data from sample stands (see figs. 5 and 6 in Keane, this proceedings). Probable pathways of succession or stand development are shown as arrows linking community types in the classification diagram. To provide insight for vegetation management, the classification also lists the treatments and site or stand conditions associated with each posttreatment community type (Arno and others 1985). An interactive computer program developed as a companion to this model supplies quantitative predictions of vegetal response to treatments (Keane 1987).

An alternative approach to successional classification within individual habitat types is being applied in central Idaho--in the Forest Service Intermountain Region (Steele 1984, this proceedings; Steele and Geier-Hayes 1987a, 1987b). The objectives are similar to those of Arno and others (1986), but the classifications are constructed in a different manner. Each community is divided into three strata--the tree, shrub, and herb layers. For each layer a diagram depicts the relative position of indicator species on a successional time scale, from early seral to climax (fig. 3). These successional relationships are used to designate "layer types" which collectively constitute the community type. Linkages of layer types to wildfire and prescribed fire treatments are provided based on interpretation of sample stand data.

SYNTHESIZING DETAILED INFORMATION

Finer detail in using vegetation classifications to guide fire management is hampered because fire behavior and fire effects are strongly related to other aspects of vegetation in addition to the

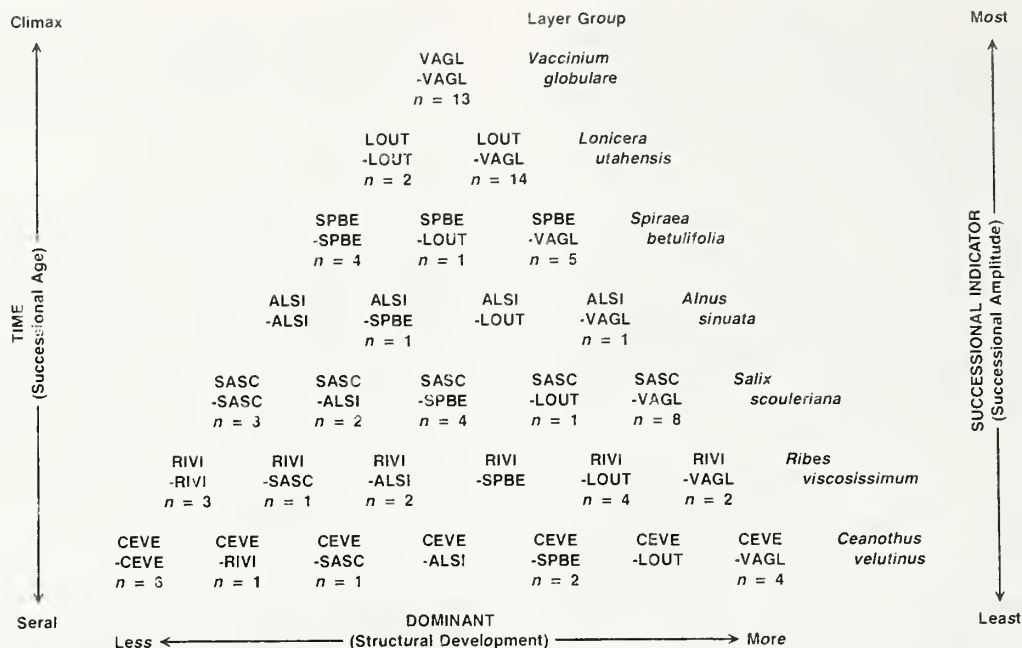


Figure 3--Classification model of shrub layer types in the *Abies grandis/Vaccinium globulare* habitat type (from Steele and Geier-Hayes 1987a).

successional community type. For instance, loadings of down woody fuels and juxtaposition of stand types contribute to how a fire burns. While characteristics of vegetation are of primary importance in managing timber, wildlife habitat, and range resources, fire managers have the additional concern of superimposing a highly variable treatment on the vegetation.

Reporting information on effects of certain kinds of fires on individual species in certain habitat types is often feasible, and may allow land managers to make more definitive predictions of fire effects. Both the Steele (1984) and Arno and others (1986) classifications presented predicted responses of individual tree and undergrowth species to fire based on sample stands. The work of Stickney (1980, 1985, 1986) and Geier-Hayes (1987), among others, also showed the response of individual species to particular fire treatments by habitat types. The Fire Effects Information System (Fischer, this proceedings) synthesizes all available fire response information by species and by plant community types. The advantage of this system is that detailed information will be made widely accessible to land management through the computer.

Land managers and specialists should, however, keep in mind that predicting response of complex vegetal communities is more difficult than evaluating responses of individual species. Moreover, fire, like natural vegetation, is itself a complex variable. Therefore it seems essential that vegetal information to guide fire management be obtained through a variety of classifications and syntheses of field observations and research information.

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ABSTRACT: Vegetative mapping projects can be designed using principles inherent to the design of soil surveys. The first step is to work with map users to identify specific objectives for the survey. Map users identify the uses for which soil is to be evaluated, the level of detail required, and the properties or attributes of soil important to map objectives. Mappers advise users about technical feasibility and cost of map objectives. Map objectives strongly influence selection of map base, map scale, kind of map units used, and mapping techniques. Soil taxonomy is used to name and describe the composition of map units. Habitat types, or similar classification systems, can be used in vegetative mapping the same way. The principal advantage of doing so is to facilitate the description of vegetative complexity within map units.

INTRODUCTION

The soil survey staff has much experience in designing mapping projects. Design of vegetative mapping projects can benefit from this experience. The purpose of this paper is to describe the steps in designing a soil survey and how they might apply to vegetative mapping projects.

SETTING PROJECT OBJECTIVES

Before a mapping project can be designed, objectives for the map must be defined. Both map users and mappers must be involved in setting objectives. The following is a partial listing of items which should be considered in setting map project objectives:

1. The uses for which the vegetation or potential vegetation is to be evaluated. Wildlife habitat, timber productivity, response to silvicultural treatment, range forage productivity, and response to livestock grazing are examples of objectives for which vegetation is commonly evaluated.

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2. The level of generalization required. Is the objective to evaluate timber productivity and silvicultural response on stands of a minimum of 5 acres in size or to evaluate suitability and limitations to timber management in a large undeveloped watershed? A good way to describe map detail is the minimum size delineation to be used.

3. The properties or attributes of vegetation that are important to map objectives. Wildlife habitat analysis will likely be based on a different set of vegetative properties than objectives for evaluating timber productivity and response to silvicultural treatment. It is important that specific interpretations and the properties from which they are derived are identified. For example, a map of elk habitat might require interpretation of hiding and thermal cover, winter forage value, summer forage value, and calving habitat. The biologist should specifically identify which vegetative properties determine suitability for each element of habitat.

There are some difficulties in working with users to set map objectives. The most common is the tendency of users to combine too many objectives in a single map project. They will reason that as long as you're in the field, you might as well gather all the data they might need. Maps may have multiple objectives provided they require the same level of map detail and are based on the same, or closely related, sets of properties. Incompatible objectives greatly increase the number of delineations on the map, which in turn obscures information important for any given objective and greatly increases project costs.

Map users will sometimes identify objectives requiring different levels of detail. For example, they may desire a map which allows the evaluation of large areas for timber management and response by individual stands to silvicultural treatment. A good strategy to use in this situation is to map the entire area at the broadest level of detail required. This map, in turn, is used to identify which areas should be mapped in greater detail for the second objective. Such an approach produces legible maps which are less expensive than those obtained by detailed mapping of an area without prior knowledge of its general features.

In summary, mappers need to specifically understand user's objectives before designing map projects. Project success will be judged by the user based upon how well their expectations are met. In turn, users need to understand how objectives affect map quality and cost. It is

preferable that the user understand which objectives are technically or economically impractical in the project planning stage rather than have their expectations for the project not met. Once project objectives are established, the mapper may begin designing the project.

MAP BASE AND MAP SCALE

One of the first decisions in the design of a mapping project involves the selection of a suitable map base and scale. Map bases are usually photographs which display vegetative and land use patterns or topographic maps which display slope and relief. Either type of map base may be appropriate to a project depending upon the types of properties to be mapped and their relationships to properties visible on the base. The map base selected should be the one which provides the user with the best understanding of such relationships.

Selection of map scale is determined by the minimum size delineation required to meet project objectives. This minimum size delineation is commonly about 1/4-inch square (about 5 acres at 1:24,000 scale or 40 acres at 1:63,360 scale). Users who need information about small areas are not distracted by numerous boundaries and symbols, hence, a minimum scale map base is appropriate. Users who evaluate large areas are distracted by cluttered maps; consequently, the map base scale selected is usually larger than that required for minimum size delineations.

NAMING AND DESCRIBING MAP UNITS

Every map needs a legend in which map units are named. Map units on soil maps are named for kinds of soil. Map units on vegetative maps will be named for habitat types or classes in some equivalent classification system. It is important for mappers to recognize that the classes in classification systems are conceptual. They provide a common standard for naming, interpreting and communicating. Map units named for these classes contain real soils or plant communities. Map units named for a single kind of soil or plant community will almost always contain soils or plant communities with properties outside the range of the named soil or plant community. They are mapping inclusions. Inclusions cannot be excluded from delineations by practical field mapping methods because of natural variability. When map units are designed and named, judgment must be exercised about the effect of inclusions on map objectives. In soil surveys, inclusions that have properties that cause them to behave like the named soil for map objectives are treated as similar. If inclusions have properties that cause them to behave differently than the named soil, they are treated as dissimilar. Dissimilar soils are of minor extent and do not affect map objectives. Similar inclusions can be extensive, but are not dominant. These principles can be used when naming and designing vegetative map units.

Following are two examples of how vegetative map units might be named and their composition described using formats from soil surveys.

Map Unit A: Subalpine Fir/Beargrass

This map unit is on southerly aspects at 4500 to 6000 feet elevation. Subalpine fir/beargrass is the major habitat type. Douglas-fir/blue huckleberry, beargrass phase is included at lower elevations and is similar. These habitat types occupy about 85 percent of the unit.

Included are up to 15 percent dissimilar habitat types. Subalpine fir/bluejoint is in moist draws and the forest understory has higher productivity for elk forage. Subalpine fir/menziesia is on included northerly aspects and has higher value for elk security cover.

Map Unit B: Ponderosa Pine/Idaho Fescue-Douglas-Fir/Ninebark Complex

This map unit is on dissected mountain slopes at 3000 to 4500 feet elevation.

Ponderosa pine/Idaho fescue is the major habitat type on southerly aspects. Douglas-fir/Idaho fescue is similar on upper slopes. These habitat types occupy about 50 percent of the unit.

Douglas-fir/ninebark is the major habitat type on northerly aspects. Douglas-fir/snowberry is similar on lower slopes. These habitat types occupy about 40 percent of the unit.

Included are up to 10 percent dissimilar community types. Small meadows dominated by Idaho fescue and bluebunch wheatgrass are on narrow ridges and have higher forage productivity than the major habitat types.

MAPPING TECHNIQUES

The level of detail required by map objectives affects selection of field mapping techniques. Objectives requiring detail and high purity of map units will require mappers to sample each delineation to verify its composition and boundary. This is very expensive; consequently, map projects will be for small areas such as research plots or areas scheduled for intensive vegetative treatment.

Objectives requiring less detail and purity permit mapping techniques that rely on sampling of representative delineations and extrapolation of ground truthed data to unsampled delineations via aerial photo or remote sensing interpretation. These mapping techniques require enough ground truth sampling to establish reliable relationships between sets of properties important to map objectives and an aerial photo or remote sensing

"signature". Intensive ground truthing may be required for general map objectives when adequate signatures cannot be found. Mappers and map users should reassess map objectives if this situation happens frequently. It is important to note that reliability should be set by map objectives and not by the mapping technique employed. If map users have requested unrealistic levels of reliability given time and funds, they should be notified, and a decision made as to the appropriate sampling technique to employ.

PROJECT EXECUTION

The following is a partial listing of quality control practices used in soil surveys which should be considered in vegetative mapping.

1. Map units should be tested against objectives during mapping. Each map unit should have a unique set of interpretative values and properties which relate to project objectives. Unnecessary map units clutter the map and obscure needed information.

2. Every map project should have a report. A map and legend cannot convey all needed information to the user. There are always properties or variabilities that cannot be described without narrative description.

3. A legible map is the first requirement for success. Cartographic qualities such as line weight, symbol placement, and delineation density should receive attention.

SUMMARY

Vegetative mapping projects should be carefully planned to insure project success. Users should be consulted to set objectives and establish relationships between objectives and properties of vegetation. Mappers should advise users concerning the technical feasibility and costs of achieving objectives. Selection of map base, map scale, types of map units used, and mapping techniques are all strongly influenced by objectives. A narrative report that describes composition of map units and properties important to project objectives is recommended.

CONCEPTS AND TECHNIQUES OF VEGETATION MAPPING

David W. Roberts and Stephen V. Cooper

ABSTRACT: Mapping vegetation involves plotting the distribution of vegetation classes on base maps. This paper distinguishes between mapping potential vegetation (habitat types) and current vegetation (community types) and addresses the characteristics unique to each problem. Guidelines are presented for effective sampling of vegetation, predictive models for vegetation mapping are compared, and methods for validation of the predictive models and the completed maps are presented.

INTRODUCTION

Vegetation comprises the largest biotic component of natural ecosystems, and directly or indirectly determines the distribution and abundance of many other natural resources. One of the common objectives of vegetation classification is to create classes that can then be mapped to portray the distribution of the vegetation characteristics on the landscape. Such maps provide valuable information for many land management practices. The objective of this paper is to present some guidelines for mapping vegetation using existing classifications, and to introduce or review some useful techniques. We provide only cursory guidelines on the actual field procedures of vegetation mapping. Instead, we focus on procedures for extrapolating ground-truth mapping data to large unmapped areas, and on methods of map validation.

IDENTIFYING FACTORS CONTROLLING VEGETATION DISTRIBUTION

Throughout this paper, we distinguish between two different but related objectives of vegetation mapping. One common objective is to map potential natural (climax) vegetation (habitat types in the sense of Daubenmire and Daubenmire 1968) from existing vegetation patterns. Strictly speaking, this should be considered site mapping (of physical or abiotic factors), rather than vegetation mapping, but it is commonly considered an aspect of vegetation mapping. Alternatively,

the objective may be to map existing vegetation according to a successional community classification (for example: Arno and others 1984; Steele and Geier-Hayes 1987) or by dominance types. The primary reason for distinguishing between potential vegetation and existing vegetation (however classified) is that the distribution of the two is determined by different sets of factors, and it is these factors that form the basis of predictive models of vegetation distribution.

Aside from artifacts in the migration of flora over time, the distribution of potential natural vegetation is determined strictly by factors of the physical environment. The radiation, moisture, and nutrient budgets are the primary determinants. Although the radiation budget of sites is relatively difficult to measure effectively, potential direct radiation can be computed from latitude, aspect, and slope (Swift 1976). The effect of shading from adjacent landforms is difficult to estimate, but algorithms (see Austin and others 1984) and templates exist for calculating the portion of the sun's trajectory blocked by adjacent landforms for specified days of the year. In practice, except for extremely dissected terrain, the effect of shading can be ignored; if necessary an ancillary variable can be introduced to simulate shading. If estimates of diffuse radiation are then added to estimated direct radiation, it is possible to estimate the daily radiation received by a site, and then to integrate over seasons or a year. When radiation is not computed directly, a utilitarian radiation index can be calculated as:

$$\text{index} = (-\cos(\text{azimuth}-30) + 1) / 2.$$

Index values range from 0.0 on NNE slopes to 1.0 on SSW slopes.

Moisture budgets are also difficult to measure, but can be estimated from topographic and soils data. The relative moisture budget of a site is determined primarily by elevation, topographic position, and soil characteristics. In areas with sufficient weather stations it is possible to estimate the increase in precipitation that occurs with an increase in elevation using a linear regression model. If available precipitation data are insufficient, it is reasonable to assume that relative precipitation is linearly proportional to elevation, at least for sites not on the elevational extremes. Caution should be exercised in extrapolating elevation-precipitation regressions beyond the immediate area for which they are derived; in the northern Rocky Mountains where the spines of many mountain ranges are oriented north-

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south, windward west slopes are more moist than east slopes at the same elevation.

Topographic position, soil texture, and soil depth determine the proportion of precipitation that is available to vegetation on a site by controlling run-on and run-off, as well as soil moisture storage and availability (Hewlett 1982; Pritchett and Fisher 1987). Distance from open water and adjacent stream order also serve as useful indices to site moisture availability (Martin 1970). In some mountainous and foothill terrain, prevailing winds strongly modify the moisture-temperature regime and vegetation pattern. Prevailing winds affect site moisture balance through increases in precipitation or evaporation. These effects can be modeled by creating a categorical variable for the specific range of aspect directly opposed to the prevailing winds.

Finally, those aspects of the nutrient budget that determine potential vegetation distribution are determined in part by the chemistry of the soil parent material and soil cation exchange capacity (Pritchett and Fisher 1987). It is not necessary to know the relative nutrient values of the different parent materials, but rather simply to allow for their contributions to the predictive model. Often, classifying diverse parent materials into a few classes such as calcareous sedimentary, noncalcareous sedimentary, mafic igneous, felsic igneous, and metamorphic is sufficient. As we will explain, fragmenting environmental variables into numerous class variables may cause difficulty in developing a predictive model.

Employing this method of predicting potential natural vegetation, radiation is calculated from latitude, aspect, and slope; moisture is indexed by elevation, geographic and topographic position, soil texture and soil depth; and nutrient status from parent material. All these data can be derived from topographic, soils, land type, or geological stratigraphy maps. Because it is the current vegetation, rather than the potential vegetation, that is evident in aerial photography or remote sensing imagery, these sources of information must be used with caution. The same successional community can occur in several potential vegetation types and may obscure differences in potential vegetation.

In contrast, the distribution of successional community types is determined largely by disturbance type (including management practices), prior community composition, and chance. Following a disturbance, chance may play a large role in determining the resulting vegetation, as for example differences in cone crops for tree species in adjacent stands causing one of several possible tree species to become dominant. This stochastic effect greatly increases the difficulty in predicting successional communities for areas recently disturbed. Little or none of the information necessary for prediction may be available on maps, especially if maps of disturbance events (such as fire boundaries) are not available. However, the physical environment limits the set of possible successional communities at any

given site, and it is helpful to have or simultaneously develop a potential vegetation map to aid in predicting successional community types on the landscape. Additionally, because the objective is to map what is currently present, aerial photography and remote sensing imagery are extremely useful.

OBTAINING GROUND-TRUTH MAPPING DATA

Assuming typical time and resource constraints, any large mapping effort will require the extrapolation of limited ground-truth data to a much larger area. Whether mapping potential vegetation or current vegetation, effective stratification is essential; the stratification must reflect the factors that control the distribution of the vegetation.

For potential vegetation, the controlling factors are parent material, soil texture and depth, elevation, aspect, slope, and topographic position. The simplest procedure is first to delineate the area into parent material classes. Soil texture and depth are likely to be highly correlated within the parent material classes, but substantial variation may still exist. If soils maps are available, depth and texture classes should be delineated within the parent material classes. This two-step stratification leads to fairly homogeneous regions. A roughly comparable level of stratification can be obtained from land type maps being compiled for each National Forest by the Forest Service, U.S. Department of Agriculture.

Elevation, aspect, and slope are continuous variables, and it is not necessary or advisable to formally delineate elevation or aspect classes within the parent material--soil strata previously identified. Choose areas for mapping that exhibit sufficient topographic relief to expect potential vegetation differences, but which are not characterized by fine-scale or microtopography. These areas should consist of several hundred acres so that many topographic positions are represented, and should be chosen to represent, in the aggregate, all elevation and aspect combinations within the region. While collecting the ground-truth data, the mapper should keep a running list of elevation and aspect combinations mapped, so that common areas will not be oversampled and less common combinations missed. It is important to map areas large enough that several potential vegetation types are included, so that the local pattern of adjacent types is determined. In addition to helping in validation of the map, some extrapolation techniques can make use of adjacent vegetation types in a predictive model.

For mapping successional vegetation (community types), a different stratification is employed. If the potential vegetation has been previously or simultaneously mapped, this should serve as the first level of stratification. Aerial photography can then be used to delineate apparently homogeneous areas. Finally, if maps of the distribution of previous fires, or if fire history data are

available, this information can also be entered into the stratification.

The scheme for sampling existing vegetation within strata is more problematic than for potential vegetation because the classes bear no necessary relation to position on the landscape, and it is difficult to determine the set of successional community types that exists in a region. The approach we have employed is to map relatively large sample areas and determine which successional community types occur within each potential vegetation type. Frequently, depending on the disturbance regime for the area, relatively few of the potential community types actually occur on the landscape. These communities are then correlated with stand age (if known), aerial photography color or texture, and remote sensing spectral signatures (if available). If remote sensing data are to be used, the sample stands must be sufficiently large and homogeneous to ensure that reliable spectral data can be obtained for these stands without blending or noise from adjacent types.

EXTRAPOLATION OF GROUND-TRUTH DATA

Ground-truth data can be extrapolated based on either a special-purpose model developed by the mapper, or by a statistical model using a computer. Statistical models have advantages in sophistication and objectivity, but vegetation distribution does not fit easily into the assumptions underlying many statistical models, and a carefully prepared special-purpose model may provide greater accuracy. The primary advantage of statistical models is the great speed with which they can process the data and predict class membership for new areas to be mapped.

The first step in developing a special-purpose model is to classify variables as categorical variables, which have classes but no necessary order (for example, parent material), or scalar variables, which are ordered from low to high (for example, elevation). Categorical variables are suitable for development of dichotomous keys; scalar variables can be used in quantitative indices. Examine the categorical variables first, searching for variables that partition the vegetation types fairly cleanly. For example, igneous parent materials may support one set of potential vegetation types; sedimentary parent materials support another. Even if the two sets overlap, distinguishing the parent material narrows the possible choices. Using the variable that achieves the best split first, repeat the process for each of the two branches in the tree until there are no clean splits left. Then, for each branch of the tree, develop a predictive model from the scalar variables by plotting the distribution of vegetation classes using the scalar variables as axes. Vegetation classes of mid-slope positions are effectively plotted by locating sample plots by elevation and aspect on polar coordinate graph paper. While the special-purpose model admittedly is subjective, it is essential to allow as little ambiguity as possible, as ambiguous choices lead to frustration

when attempting to use the model for numerous stands.

If statistical models are preferred, there are at least two choices--linear discriminant analysis (LDA) and classification trees (CT). LDA is similar to linear regression, but the objective is the prediction of class membership for new objects in existing classes (Afifi and Clark 1984). CT is a computer algorithm that employs a procedure similar to that outlined above for the special purpose model (Breiman and others 1984).

LDA weights and combines data from samples of known classes to form a linear function that best reproduces the original classification (Verbyla 1986). This linear function is known as the "discriminant function" or "classification function" (Afifi and Clark 1984). Values of the classification variables for each stand of vegetation are entered into the linear function to predict to which of several classes it should be assigned. Depending on the computer program employed, the item may simply be assigned to the class with the highest probability, or the probability of membership in each class may be reported. LDA can employ some scalar variables directly, but categorical variables must be entered as dummy variables (1 or 0) for each possible class.

LDA has several limitations for predicting vegetation distribution. If there are numerous parent material and soil textures, the number of dummy variables gets very large; if the number of possible predictor variables is large relative to the sample size, serious bias in prediction may result (Verbyla 1986). Second, vegetation distribution may be highly nonlinear with respect to environmental variables; LDA will nevertheless attempt to fit a linear relation. For example, if slope aspect is not transformed to reflect radiation or temperature gradients, LDA will attempt to use the aspect values as a linear scale from 0 to 360. Third, LDA is susceptible to outliers (unusual points) and noise (sampling error or random variation) (Verbyla 1987). Additionally, assumptions regarding the variance/covariance structure of the data employed in LDA are commonly violated by vegetation-site data. However, LDA is still commonly used as it provides an objective method for prediction, is well understood, and is widely available on computers.

Steele (1986) used logistic discriminant analysis, a more robust discriminant technique, for terrain-vegetation modeling. In a comparison to LDA, the logistic discriminant analysis was notably more accurate; an additional 15 percent of the plots were correctly classified. We are currently investigating the value of logistic discrimination in vegetation mapping.

CT is a partitioning technique that forms dichotomous keys from sample data (Breiman and others 1984). Each variable is examined in turn to determine the optimal split point (for scalar variables) or optimal partition (for categorical variables) to produce the most homogeneous classes. The variable with the best split is

employed first, and the procedure is then repeated for each branch of the tree to produce an optimal dichotomous key. CT assumes that the relation between vegetation and scalar environmental variables is monotonic, rather than linear, and is much more flexible than LDA in choosing and combining variables. CT is much less susceptible to outliers and noise than is LDA (Verbyla 1987). As a final product, CT provides a dichotomous key, rather than the probability distributions and linear functions provided by LDA, to predict the membership of new samples.

Unfortunately, CT is computationally intensive. For each scalar variable, for N unique values, there are N-1 possible split points, each of which will be examined. For categorical variables, the number of possible splits is potentially much greater, according to the formula:

$$\sum_{X=1}^{(N-1)/2} \frac{N!}{X!(N-X)!}$$

if N is odd

$$\sum_{X=1}^{N/2} \frac{N!}{X!(N-X)!}$$

if N is even

For five possible values, the number of splits is only 15; for 10 possible values the number becomes 637 possible splits. The run-time for the program is approximately proportional to the number of splits, so that categorical variables with large numbers of possible values should be avoided. As a final disadvantage, CT can be expensive to run and is not widely available.

MAP VALIDATION

Regardless of the method used to map new areas, the models employed or the maps so constructed must be validated. The apparent accuracy of predictive models is assessed by comparing the predicted values to the sample values. The apparent accuracy is subject to bias, however, as the same data are used to develop and test the model. The bias can be estimated and reduced by cross-validation (Verbyla 1986). In cross-validation, the data are divided into a number of groups. The data in one group are held out, and the model is developed on the remaining groups. The values of the samples held out from the model are then predicted and compared to the actual values. This procedure is repeated until all groups have been held out once in turn, and the model has been developed n times for n groups. The fraction of correct predictions is the cross-validated accuracy, and the difference between the apparent accuracy and cross-validated accuracy is an estimate of the model bias. Cross-validation methods vary in the relative amount of data used for development and testing, and are reviewed by Verbyla (1986).

Alternatively, the models can be tested with the bootstrap resampling method (Efron 1983; Verbyla 1986). Bootstrapping involves withdrawing a number of samples at random with replacement, and developing the model on the remaining samples. The values of the withdrawn samples are predicted

and compared to the actual values. This process is repeated a large number of times, and the mean number of correct predictions is the bootstrap estimate of model accuracy. Bootstrapping provides better estimates of accuracy than does cross-validation, but requires considerably more computer time to calculate.

Ideally, the predictive model should be developed for data collected one year, and employed to map sufficient area for testing the following year. The test set should be chosen as a stratified random sample of stands. If random points are chosen, rather than random stands, the points should be discarded if they are in areas of nonhomogeneous topography or near apparent ecotones. When the test stands are compared to the predicted values, it is possible to identify which portions of the predictive model failed, at least for the special purpose and CT models. In these cases it is possible to redirect the sample design to collect more data in problem areas and to reduce sampling where the model predicts sufficiently well.

APPLICATIONS

Both LDA and CT were employed in an effort to map potential vegetation in Bryce Canyon National Park, based on a classification by Youngblood and Mauk (1985). Bryce Canyon National Park, an area of approximately 50 square miles in southern Utah, is on the eastern edge of the Paunsaugunt Plateau at elevations from approximately 6,800 feet to 9,100 feet. The forested portion is mixed conifer forest, principally in areas of climax ponderosa pine (Pinus ponderosa), Douglas-fir (Pseudotsuga menziesii var. glauca), and white fir (Abies concolor).

A total of 125 sample plots of forest vegetation were stratified in the field by elevation, aspect, topographic position, and parent material. Sample plots were keyed to the P. ponderosa (PIPO), P. menziesii (PSME), or A. concolor (ABCO) series (climax tree species). The blue spruce (Picea pungens) series is present in the Park, but is too rare to predict reliably.

Ground-truth mapping indicated that the distribution of series was determined primarily by the radiation and moisture budgets. For all sample plots, mid-July radiation (concurrent with estimated onset of moisture stress) was calculated from latitude, aspect, and slope (Swift 1976), and precipitation was estimated simply from elevation. The sample plots were then divided randomly into 10 groups for analysis and 10-fold cross-validation for both LDA and CT.

For the LDA, sample plots were assigned to the series with the highest value for the discriminant function (see example, table 1). The apparent accuracy of the model (using all data) was 80 percent, with a 10-fold cross-validated accuracy of approximately 70 percent (table 2). The cross-validated estimates show fair performance for the PIPO series, poor performance for the PSME series, and good performance for the ABCO series. The

same 10 groups were analyzed by CT using elevation, radiation, and slope as classification variables. The apparent accuracy was 83 percent, with a 10-fold cross-validation estimate of accuracy of approximately 64 percent (table 3). Again, the model exhibits fair performance for the PIPO series, poor performance for the PSME series, and good performance for the ABCO series. The classification tree for the full data set is shown in figure 1.

Table 1--Linear discriminant model for predicting series. Determine appropriate series by calculating maximum probability function

$$\text{Probability} = \text{elevation} * c1 + \text{solar radiation} * c2 + \text{constant}$$

Series	c1 elevation (feet)	c2 solar radiation (langleys)	constant
PIPO ¹	0.080	0.125	-369.0
PSME ²	0.085	0.103	-393.0
ABCO ³	0.090	0.096	-429.0

¹PIPO = P. ponderosa series

²PSME = P. menziesii series

³ABCO = A. concolor series

Table 2a--Apparent accuracy of LDA for full data set. Number of plots (with percent of actual in parentheses) is given for each combination of predicted and actual series

Actual	Predicted		
	PIPO	PSME	ABCO
PIPO	23 (77%)	6 (20%)	1 (3%)
PSME	6 (19%)	16 (52%)	9 (29%)
ABCO	4 (6%)	3 (5%)	57 (89%)

mean = 80 percent correct

Table 2b--Cross-validated accuracy of LDA for full data set. Number of plots (with percent of actual in parentheses) is given for each combination of predicted and actual series

Actual	Predicted		
	PIPO	PSME	ABCO
PIPO	19 (63%)	10 (33%)	1 (3%)
PSME	8 (26%)	11 (35%)	12 (39%)
ABCO	4 (6%)	3 (5%)	57 (89%)

mean = 70 percent correct

Table 3a--Apparent accuracy of CT for full data set. Number of plots (with percent of actual in parentheses) is given for each combination of predicted and actual series

Actual	Predicted		
	PIPO	PSME	ABCO
PIPO	27 (90%)	3 (10%)	0 (0%)
PSME	6 (19%)	20 (65%)	5 (16%)
ABCO	5 (8%)	2 (3%)	57 (89%)

mean = 83 percent correct

Table 3b--Cross-validated accuracy of CT for full data set. Number of plots (with percent of actual in parentheses) is given for each combination of predicted and actual series

Actual	Predicted		
	PIPO	PSME	ABCO
PIPO	23 (77%)	7 (23%)	0 (0%)
PSME	18 (58%)	4 (13%)	9 (29%)
ABCO	6 (9%)	5 (8%)	53 (83%)

mean = 64 percent correct

- 1) elevation \leq 8420 feet
- 2) slope \leq 17.5 percent
 - 3) elevation \leq 8090 feet PIPO (22/32)
 - 3) elevation $>$ 8090 feet
 - 4) elevation \leq 8330 feet .. PSME (6/ 8)
 - 4) elevation $>$ 8330 feet .. PIPO (3/ 4)
- 2) slope $>$ 17.5 percent
 - 5) elevation \leq 7230 feet PIPO (2/ 2)
 - 5) elevation $>$ 7230 feet PSME (10/13)
- 1) elevation $>$ 8420 feet
 - 6) slope \leq 4 percent
 - 7) elevation \leq 8620 feet PSME (4/ 4)
 - 7) elevation $>$ 8620 feet ABCO (3/ 3)
 - 6) slope $>$ 4 per cent ABCO (54/59)

Figure 1--Classification tree for predicting series for sample plots. For each terminal step of the key, the number of correct identifications and the total number of plots terminating at that step are given in parentheses.

The performance of both approaches reinforces our intuitive model of the distribution of series. The distribution of climax *P. menziesii* appears to cover a narrow range of environments in Bryce Canyon, and the differentiation between the PSME series and the other series is extremely subtle. Both of the objective approaches employed here performed poorly in distinguishing this series, with relatively greater success for the other series. For both approaches, the mistake is to assign PSME series plots to other series, rather than to assign other series plots to the PSME series.

The results demonstrate the need to perform cross-validation (or some other form of error checking) on the predictive models. The apparent accuracy for both models was significantly higher than the cross-validated accuracy, with prediction biases of 10 percent for LDA and 19 percent for CT. For

predictive models developed on larger data sets, the expected prediction bias should be smaller, but the apparent accuracy will always be higher than the actual accuracy of the model.

In this example, LDA performed better than CT, but previous experience in comparative tests suggests that results vary among data sets. CT is possibly more sensitive to small data sets, and we are currently investigating the relative performance of these techniques on much larger data sets.

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VEGETATION MAPPING IN THE NORTHERN ROCKY MOUNTAINS

Barry L. Dutton

ABSTRACT: Vegetation mapping in many guises has been conducted throughout the northern Rocky Mountains. Cover types, habitat types, range sites, grizzly bear components, timber stands and vegetation types are examples of the mapping unit components used. Goal, costs, and success have varied. Most vegetation mapping data are not published and are not in a form for easy general access. New technologies including Geographic Information Systems should allow easier, more widespread use of vegetation mapping data and better communication among mappers. Vegetation mapping projects have many components and each must be planned for to ensure success.

INTRODUCTION

This paper reviews past vegetation mapping efforts in the northern Rocky Mountains and summarizes some important characteristics including mapping unit components, scales, acreages, and costs. Guidelines for conducting vegetation mapping projects are summarized with emphasis on proper planning and complete reporting of results.

NEEDS FOR VEGETATION MAPPING

Vegetation maps are used for a variety of purposes by many disciplines. This presents a dilemma to map makers who must decide whether to make a vegetation map with one purpose in mind or to try to satisfy the needs of several user groups. It is important for the mapper to know as much as possible about each discipline with potential use for the map. This can be achieved by extensive interdisciplinary training (the superman syndrome), or by involving specialists from different user groups in all phases of project planning and review.

PAST VEGETATION MAPPING EFFORTS

I will first review some examples of past vegetation mapping projects. This review is not comprehensive but illustrates the range of goals, intensities, and other characteristics of existing maps.

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Several published vegetation maps are available that cover large areas of the northern Rocky Mountains. These include maps of potential vegetation such as Kuchler's map of the United States (1966) and Ross and Hunter's map of Montana (1976). Other large-area maps address individual species distribution such as Arno's map of Larix lyalli distribution (1970) or Morris and Kelsey's map of Artemesia spp. distributions (1973).

Most mapping projects, however, cover smaller areas and are designed for specific purposes. Table 1 illustrates some examples of recent vegetation mapping projects and their characteristics. Costs are for map preparation and do not include planning, materials, data compilation, report writing, and other tasks. These data suggest that many vegetation mapping efforts have similar costs for fieldwork. This is due to the fact that field methods are similar and involve a combination of map or photo interpretation and transects across the landscape for direct observations. The major differences in mapping projects are therefore in the expertise of individual field crew members and in the specifics of what data are recorded.

Habitat Type Mapping

Mapping habitat types has been popular among most state and federal agencies as well as large private forest land owners. Habitat type maps at various scales are available for many national forest and state forest lands in Montana. As greater interest has developed in using habitat type maps, further map refinement has occurred. The cost of mapping habitat types ranges from a few cents per acre for small-scale projects covering large areas to between 25 and 50 cents an acre for more detailed efforts at scales near 1:24,000.

Most mapping projects treat the taxonomic unit of habitat type as a mapping unit and do not have map unit descriptions explaining the actual distribution of types within map delineations. These maps are used for a wide range of planning and project purposes. They have proven useful both as a communications tool and as a source of substantial management information related to habitat types. The concept of habitat types is firmly planted in resource agencies and research institutions and will continue to be widely used.

Table 1--Examples of vegetation mapping projects and costs for map preparation

Project Area	Map Units	Method	Scale	Acres	Costs (\$/Acre)
Seeley Ranger District	Habitat types	Ground truth	1:24,000	55,000	0.27
Seeley Ranger District	Habitat types	Photo-interp	1:24,000	80,000	0.02
Lolo National Forest ¹	Habitat types	Ground truth and photo-interp	1:31:680	700,000	0.01
Crow Indian Reservation ¹	Range sites	Ground truth	1:24,000	1,200,000	0.16
BLM Dillon Resource Area	Range sites	Ground truth	1:63,360	748,000	0.33
Greenough Coop Grazing Association ²	Range sites	Ground truth	1:24,000	70,000	0.28
Lewis and Clark National Forest	Timber stands	Photo-interp	1:24,000	134,169	0.02
Glacier National Park and Flathead National Forest	Vegetation types	Ground truth	1:24,000	33,500	0.60

¹Ringleb, Rick. 1987. [Personal communication]. November 3. Huson, MT: Resource Analysis.

²Kennett, Greg. 1987. [Personal communication]. November 5. Missoula, MT: Missoula County. Soil Conservation District.

Range Site Mapping

Range site mapping has been most popular with the Soil Conservation Service and the Bureau of Land Management. Range sites are a combination of soil, climate, and vegetation factors. This method has been developed for both grasslands and "grazable woodlands." Fieldwork mapping costs range from 15 to 50 cents per acre depending on scale, goals, and other factors. These mapping projects have also usually treated the taxonomic unit of range type as a mapping unit and lack map unit descriptions explaining the actual distribution of types within map delineations. These maps have also proven their long-term usefulness, again due to research linking plant composition and production to the types. It is likely that range site mapping will continue to be used in rangeland communities.

Timber Stand Maps

Timber stand or timber type maps are a form of vegetation map that is often overlooked. With improvements in recent years, these maps offer an excellent resource in areas with no other

vegetation information. Skilled plant ecologists can expand these maps into vegetation type and habitat type maps with additional work. Most agencies and private companies with forest land holdings have classified their lands according to a timber type mapping system. Some maps use Society of American Foresters cover classes but recent classification schemes are much more sophisticated and informative. Most of the forest lands in the Forest Service Northern Region have type mapping. This work has mainly been accomplished by air photo interpretation and with limited ground-truthing. Costs have usually been less than 10 cents per acre. These maps will continue to be refined and updated for timber management purposes.

Grizzly Habitat Component Mapping

Grizzly bear component maps have been prepared for much of the grizzly habitat and some potential habitat in the northern Rockies (Leach 1986). Habitat components are delineated, which represent general vegetation conditions perceived as being important to bears. Examples of components include "avalanche chutes", "wet meadows", "mixed shrub fields," and others. This

mapping method fell short of its goals and expectations. Problems included the lack of relationships to existing vegetation classifications and insufficient or erroneous documentation of community types and individual species. Costs for fieldwork were approximately 30 cents per acre (Weaver 1987). After careful evaluation of component mapping goals and results, Forest Service Northern Region wildlife personnel have worked with the regional ecology staff to implement a more detailed method of collecting vegetation information for habitat evaluation. Greater emphasis is being placed on delineating current and potential vegetation according to established classifications and methods. This method lets mappers use existing data on habitat types and other vegetation classifications. It also allows production of maps that are useful to various disciplines.

Vegetation Type Mapping

In 1986 the Forest Service Northern Region Ecology Program began producing maps of vegetation distributions based on the "vegetation type," a combination of current and potential vegetation characteristics. One goal of this method is to produce a map with utility for many user groups. Costs for fieldwork should be competitive with other methods and yield superior results. Data from the 1986 field season will be used to attempt correlations between vegetation and spectral classes in Glacier National Park and on the Flathead National Forest. Ecology Program personnel are compiling a manual on vegetation mapping to provide direction for mappers and to standardize methods for future projects.

Other Vegetation Maps

Numerous smaller mapping projects have been conducted locally. Habitat type maps and maps of current vegetation have been compiled for research areas, experimental forests, timber sales, and other locations. Current vegetation maps have been made for small nature areas, wildlife refuges, and private properties. While these projects cover relatively small areas, they represent some important botanical locations and will be the source of useful information for the future.

VEGETATION MAPS FOR THE FUTURE

With this wealth of experience in vegetation mapping, it seems we should be ready to design the ideal mapping system. However, there is considerable discussion about many basic issues in map project structure. Some believe that one map can be generated to fulfill most needs of the various user groups. This approach would allow one field crew to produce a map instead of several groups mapping the same area independently.

New technologies such as Geographic Information Systems (GIS) will have a major impact on vegetation mapping. Their greatest impact may be the enhancement of communication among various map user and producer groups. A GIS provides a centralized database to which all parties contribute. This effort may focus on creating a single vegetation map of the area, which is constantly refined as each group makes further investigations. If the "single map" approach is not adopted, a GIS will allow projects to be stored separately and integrated as needed. No matter what approach is taken toward vegetation mapping, a GIS will enhance communication between map users and producer groups, leading to maps that are more complete and more accessible.

Mapping projects are very complex undertakings. Despite a history of vegetation mapping experience in the northern Rocky Mountains, most projects lack important components which add significantly to their overall usefulness and accessibility. Vegetation mapping projects are often undertaken by individuals with expertise in some particular aspect of vegetation and it is these aspects upon which the map focuses. However, it is important to have an awareness of all components of a mapping project, how they fit together, and how each task leads to a finished product. Failure to plan for each component may diminish the usefulness of the final product.

The quality of a mapping project is directly related to the knowledge and experience of the participants. A team of several experienced vegetation mappers can accomplish much more than an army of untrained enthusiasts. In the northern Rocky Mountains, vegetation distribution and structure is very complex. Relationships to climate, landforms, soils, and other features present a nightmare to those making stratifications. It is absolutely essential that mapping project planners obtain the quality of expertise needed for all phases of project implementation.

MAPPING PROJECT COMPONENTS

Throughout a mapping project, participants should be aware of how each task fits into the project as a whole. Figure 1 illustrates a flow chart for mapping projects.

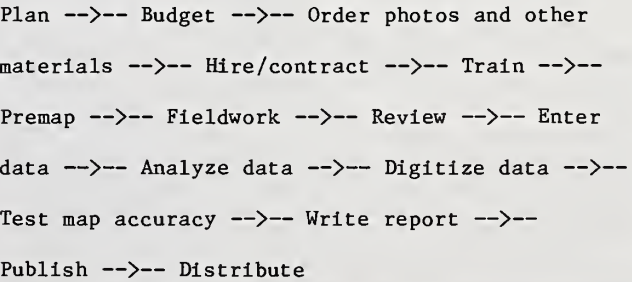


Figure 1--Mapping project flow chart.

Planning Mapping Projects

The initial planning stage is extremely important since decisions about map scale, map unit type, and other concerns will affect all subsequent activities. The national cooperative soil survey program has addressed similar questions of map unit design, map scale, map bases, logistics, and other considerations. A half-century of soil mapping experience in the U.S. is an excellent source of information for planning vegetation mapping projects. It is significant that two speakers in the mapping section of this symposium are soil scientists. Table 2 illustrates a checklist for planning mapping projects.

Table 2--Mapping project checklist

Define the area to be mapped.

Assess available resources including funds, personnel, and specialized equipment.

Choose a map base.

Choose a map scale.

Determine priority user(s)--in some cases a project may be organized and designed for a specific purpose or user group; this is usually the group paying for the project.

Establish a tentative completion date for priority user(s).

Design a map unit description format which includes the information needed by the priority user(s) and the agency as a whole.

Identify a vegetation stratification that will meet project needs. Set standards for delineating strata or polygons and for describing map units.

Determine personnel requirements to match skills and time frame for the mapping project.

Investigate special considerations such as access, wilderness classification, road closures, harvest activities, unusual weather, or other factors which affect project efficiency.

Establish a procedure for evaluating the quality of the mapping project which is agreeable with all parties.

Choose a format for the final product including compilation, correlation, editing, and printing.

Review plans with all potential users and cooperating agencies as well as various resource specialists (have project managers budget time for a continuing involvement in planning, administering, and reviewing the project).

Draft a schedule for ordering photos and map base materials.

Budget and Manpower Requirements

Budget and manpower requirements vary according to the goals, extent, scale, and other characteristics of each project. Table 3 illustrates some generalized manpower requirements for various components of a vegetation mapping project. Where budgets are limiting, various strategies can be devised to provide the needed vegetation mapping information. One method is to first generate a small-scale map for the entire area using air photo interpretation, spectral analysis, or other remote sensing tools. This map can be used for general planning purposes. The area can then be prioritized according to needs for more detailed information. Ten-year timber management plans, wildlife concerns, and special projects may be used to prioritize the order of detailed mapping.

Important Mapping Considerations

Mapping projects involve many considerations and I have tried to concentrate on some of the most important. This is by no means a comprehensive review, but will give the reader an introduction to the kinds of subjects which must be addressed for a successful project. It is essential that mapping project participants have good communication on the key project elements. Basic terms such as mapping unit, taxonomic unit, polygon, strata, vegetation type, cover type, and others must be clearly understood by all personnel. These terms are often used in confusing and contradictory fashion in both conversation and reports. The basic concepts of plant ecology and mapping must be understood by all mapping personnel.

Table 3--Sample mapping project manpower requirements for a 100,000-acre vegetation mapping project (these figures are very general estimates)

Task	Person-days
Planning	15 - 30
Premapping	25 - 35
Fieldwork	100 - 200
Data entry and compilation	20 - 30
Digitizing	30 - 45
Report	30 - 45
Administration	30 - 45
Contracting	10 - 30
TOTAL PROJECT	250 - 450

One of the most commonly misunderstood distinctions is between map units and taxonomic units. Whenever you delineate a polygon in a landscape you almost always have more than one thing (one Taxonomic Unit) contained within. Many projects continue to label mapping units and individual polygons as single taxonomic classes without mentioning the other vegetation components. Table 4 illustrates the relationship between map units and taxonomic units.

High-quality map unit descriptions increase the usefulness of the maps and the confidence of map users. Map unit design is an important part of project planning and provides a logical framework for maintaining organization in complex landscapes. Figure 2 illustrates a sample map unit description.

Table 4--Taxonomic components of a vegetation mapping unit common on the Seeley Ranger District, Montana

Percent	Taxonomic class	Landscape position
80	ABLA/VACA	Nearly level terrace surfaces
15	ABLA/XETE-VAGL	Short, steep, south slopes in the northern portion of the unit
5	ABLA/GATR	Around seeps and on the floodplains of small streams

Map Unit Name: ABLA/VACA - PICO Cover Type

Example Location of Typical Unit: The flat terrace landscape surrounding the intersection of the North Fork road and Elk Creek in the NE 1/4 of the NW 1/4 of Section 23, T 18N, R 15W.

Geology and Soils

Landform(s): Glacial outwash terraces

Parent material: Sandy, gravelly, cobbly, glacial outwash

Landtype: 27-7

Soil: Sandy-skeletal and loamy-skeletal, mixed, Andic Cryochrepts

Topography

Elevation range: 5500-7000 feet

Aspects: All

Slopes: 2-10% for the major vegetation type

Habitat Types	% of Unit	Site Features
ABLA/VACA	90	Occurs mostly on the nearly level surface of outwash terraces.
ABLA/CLUN, VACA	5	Occurs mostly in small depressions and kettles within the outwash terrace surface.
ABLA/XETE, VAGL	5	Occurs on steep (25-50%) terrace edges or escarpments.

Strata or Cover Types for the Existing Vegetation

Cover Type	HT(s)	% of Unit	Site Features
PICO	ABLA/VACA & ABLA/CLUN, VACA	95	Level surfaces & depressions of outwash terraces.
PICO-PSME	ABLA/XETE, VAGL	5	Terrace edges and escarpments.

Special Considerations: There are significant amounts of PSME/VACA in this unit where it is mapped south of Deer Creek.

Species Composition of Major Strata or Vegetation Type(s)

Strata/Veg Type	Species	Constancy	Coverage(%)
A	PINCON	10	90
	ABILAS	10	2
	VACCAE	10	20
	VACGLO	2	5
	JUNCOM	2	7

Interpretations

Timber Management:

Wildlife:

Recreation:

Fire:

Figure 2--Sample mapping unit description.

Map units are designed in relation to project size, scale, goals, landscape complexity, and other considerations. Mapping unit types may include those dominated by one taxonomic unit (single-taxa units or consociations), and those with extensive coverage of two or more taxonomic units (complexes).

Size and type of polygons are, to a large extent, determined by the map scale. For instance, at a map scale of 1:24,000 it is not practical to delineate areas smaller than about 5 acres. Table 5 illustrates some relationships between map scale, polygon size, and mapping unit type (adapted from USDA-SCS Soil Survey methods). These different levels of intensity in mapping are referred to as mapping "orders" by soil scientists. Project planners should select an order of mapping to fit their project goals.

Data Extrapolation

Mappers must also be aware of the many kinds of extrapolation that are a part of mapping projects. Final map quality is directly related to the quality of extrapolations. It is essential that the persons responsible for extrapolations have the needed perspective and experience. Lack of qualified personnel to make these contributions is a common cause of quality problems. Forms of extrapolation in mapping projects include:

Table 5--Relationships between mapping scale, polygon size, and mapping unit type. These figures are presented as a general guide and are subject to change due to local needs

Map scale	Polygon acreage Range (Average)	Type of mapping units
1:12,000 (or less)	1 - 20 (5)	Single-taxa units of vegetation types or phases of habitat types
1:24,000	5 - 100 (40)	Single-taxa units and some complexes of vegetation types, habitat types and phases of habitat types
1:24,000 to 1:100,000	20 - 500 (80)	Complexes of vegetation types and habitat types or habitat type groups
1:100,000 to 1:1,000,000	100 - 1000 (500)	Broad cover classes dominant species, lifeform groups or habitat type series

1. Extrapolating the characteristics of the portion of the polygon or vegetation type you view in traversing to that you do not observe.
2. Extrapolating the characteristics of polygons you visit to ones you observe from a distance with binoculars or other instrument.
3. Photo interpretation of polygon features when the polygon is only viewed on aerial photos and topographic maps.
4. Spectral class sampling and analysis for extrapolating vegetation types and mapping units.

Developing extrapolation or predictive skills is one of the most important parts of a mapper's training. The mapping process should become one of confirming predictions, not discovering mysteries. To extrapolate knowledge gained from transects and traverses, the mapper must identify relationships between vegetation and terrain features such as elevation, aspect, soil, and geologic material. The combination of these relationships becomes a mental terrain model which the mapper is continuously testing and revising. This model acts as a personal mapping tool, as a structured means of communication between mappers, and as a source of hypotheses for statistical testing and other purposes. It is essential to recognize and document mental terrain models throughout the fieldwork and report stages.

Map Accuracy Evaluation Procedures

Few efforts have been made in the northern Rocky Mountains to test the accuracy of vegetation maps. With the introduction of new technologies such as spectral analysis and new procedures such as the Forest Service Northern Region Ecodata System, accuracy checks are becoming more important to evaluate these innovations. While all projects should contain information about accuracy, it is especially important for pilot efforts.

Three accuracy types should be evaluated in mapping projects. Cartographic accuracy concerns the basic form of the map and the information placed on it (are polygons labeled correctly, do lines connect, etc.). Classification accuracy concerns the ability to predict a taxonomic class without direct, on-the-ground observation. Description accuracy includes how well the map unit and vegetation type descriptions represent true conditions at individual sites. By outlining accuracy goals and how each accuracy type will be tested, project planners can match these goals against manpower and funding requirements. Field personnel will have a better understanding of their tasks if these goals are clearly identified. These goals provide a framework for identifying areas during fieldwork which need further investigation.

Mapping Project Reports

Mapping projects in the Northern Rockies have often lacked a written report to accompany the maps and in many cases have lacked mapping unit or taxonomic unit descriptions. Throughout a mapping project, a tremendous amount of knowledge is acquired by field personnel conducting on-the-ground mapping. Vegetation mapping projects represent large financial investments and every effort should be made to capture as much information as possible for future use. Map completion alone should never be considered the final product. A written report should always accompany the maps to convey a wide variety of information to the map user. Table 6 illustrates some possible components of a vegetation project report. The effectiveness and usefulness of the final product is directly related to the knowledge and experience of field crew members and to the quality of presentation in the report.

Table 6--Sample components of a mapping project report

Statement of project goals
Identification of participants
Summary of procedures
Instructions on use of the information
Photos and/or maps
The map legend
Map unit descriptions
Discussions of vegetation distribution by current and climax type and by important individual species
Discussions of relationships between vegetation and topography, soils, climate, and other factors
Identification of areas with special mapping and description problems
Discussions of important species concerns such as endangered plants, poisonous plants, weeds, and wildlife foods
Results of modeling and other data treatment
Discussions of correlation procedures and relationship of the project to others
Evaluations of accuracy
Estimates of project costs
Needs for further work

VEGETATION MAPS: PERSONALITIES AND DYNAMICS

For the first time in print, I want to address a few important aspects of mapping projects. The first of these is the high regard which each of us holds for our own mapping. This may relate to the fact that mapping is part "art," and an artist is always touchy about people criticizing or changing his or her work. This is also related to the fact that a mapper is faced with making order out of chaos or "discrete types" out of "continuums" and there are many subjective choices to be made in this process. Not everyone makes these choices the same way, which can lead to differences in the appearance of the final map. Such differences must be recognized and evaluated in correlation procedures and by accuracy testing. Interpretive differences are not serious except when they drift too far from the concepts defined by mapping units and project goals.

For whatever the reason, egos and tempers are easily aroused during reviews and accuracy checks of maps in the field. Mappers and map reviewers simply need to recognize this fact and attempt to maintain a cooperative attitude and a healthy sense of humor. One way of achieving peace of mind in mapping projects is to stop viewing maps as permanent, inflexible resources. With GIS and other technologies, we will soon be able to update maps and add new refinements with relative ease. A new view of maps as dynamic tools should reduce some of the conflicts which upset some projects.

SUMMARY

In the past few decades, large areas of vegetation in the northern Rocky Mountains have been mapped using a variety of systems with varied success. Costs for fieldwork have ranged from a few cents per acre for small-scale maps covering large acreages to between 25 and 75 cents per acre for more detailed efforts. Few of these projects include written reports and many lack any description of mapping units. New technologies such as GIS will likely improve future efforts by improving communication among mappers and providing a centralized repository for all map data. Vegetation mapping projects require careful planning and administration to ensure success. Map unit design, extrapolation methods, accuracy testing, and reports are examples of mapping project components that should not be ignored. The quality of the final product is directly related to the knowledge and experience of field crews and administrators.

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USE OF GIS TO MAP VEGETATION IN EASTERN WASHINGTON

Glen O. Klock

ABSTRACT: Geographic Information Systems help make the job of vegetation mapping easier and more consistent. Examples are used to illustrate the use of such systems.

INTRODUCTION

Methods of mapping forest and range vegetation have changed with the advent of new technology. The earliest form of vegetation mapping involved drawing the extent of a vegetative type on maps in the field. In the late 1940's and 1950's, vegetative mappers began to use aerial photographs. Continued improvement in the transfer technology from the aerial photograph to the hard copy map has led to the many fine vegetation maps used by foresters today.

Whether mapping was by the field forester or the aerial photo interpreter, the boundary between vegetative types has to be drawn by the mapper. As these drawn boundaries are based on human judgment, the quality of the map is a direct function of the mapper's experience and skills. Thus qualitative differences occur among mappers, which often lead to map inconsistencies when more than one mapper is used on a forest or range vegetation-mapping project.

MULTI-SPECTRAL ANALYSIS

More recently, multi-spectral analysis has been successfully used as a tool to map forest and range vegetation. Whether the spectral image comes from an aircraft scanner, a satellite scanner, or the scan of a photograph, its interpretation depends upon correlating a spectral value with a given vegetative class. For example, a stand of Douglas-fir poles will have a different set of image spectral values than a ponderosa pine pole stand. Therefore, by setting the spectral band or limits for each vegetative class, computer analysis will draw a consistent boundary between our example classes of Douglas-fir and ponderosa pine.

This technique depends upon numeric values established with the computer to draw the boundary

between vegetative types. Therefore, the boundaries between vegetative types are generally more consistent throughout the map project area by this method than by the traditional method employing human judgment to draw these boundaries. Knowledge of the spectral value limits used in establishing the boundaries are extremely useful for future remapping or monitoring of vegetative conditions.

This case example of using image spectral values to identify vegetative types would work fine if each species type and stand structure type within each species had a unique image spectral value. Often stands do not have unique spectral values, or the difference in spectral values between two classes is so small it is difficult to differentiate statistically. Therefore, additional aids often need to be used with multi-spectral imagery for vegetative mapping.

Each timber stand or range cover is well known to exist because of a set of environmental parameters, primary energy, moisture, and temperature. These environmental parameters are often a function of the site position such as elevation and slope aspect, particularly in eastern Washington and northern Idaho. Within a given map project area, these environmental parameters can be correlated with vegetative types. Often a successful ecological model can be designed which predicts the potential distribution of vegetative types within a homogeneous biogeoclimatic zone.

GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) provide the opportunity to build, analyze, and display computer spatial data bases. Many "layers" of spatial data can be constructed, all geo-referenced to the same map coordinates. These layers may consist of elevation, slope, aspect, soil type, annual precipitation, and so on, which all may relate to the presence or absence of a given vegetative type on a site. Again, using an example in the analysis of a multi-spectral image, it may be determined that there is no statistical spectral difference between stands of ponderosa pine and whitebark pine. Field data, however, shows that whitebark pine is always found above 5,000 feet elevation, and the ponderosa pine rarely occurs above that elevation. This provides us the opportunity to use a GIS data layer of elevation to stratify from the multi-spectral image, through an image "masking" technique, the "pine" spectral class

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into whitebark and ponderosa pine. If further stand type stratification was needed, additional GIS layers as required by the ecological model could be used for the purpose of stratification.

In 1983-84, the vegetation on the Okanogan National Forest was mapped using Landsat multi-spectral imagery (Klock and others 1984, 1985). This successful mapping project required the extensive use of ecological models to separate the many vegetative classes mapped in the project. Each of these ecological models was used to identify the area in which a species class might occur, and the imagery confirmed its presence or absence. The output vegetation map formed a GIS data layer.

More recent developments in GIS technology permit the generation of a new spatial data layer from an algebraic equation where the parameters are represented by other GIS data layers. Ecological models were used with the image "masking" technique to locate the many different map classes used in the Okanogan National Forest Landsat vegetative mapping project. This more recent algebraic ecological model technique development

now simplifies and provides more flexibility in using GIS spatial data bases and models to map forest and range vegetation.

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THE FIRE EFFECTS INFORMATION SYSTEM:
A COMPREHENSIVE VEGETATION KNOWLEDGE BASE

William C. Fischer

ABSTRACT: The Fire Effects Information System, an authoritative source of information on the effects of fire on plant and animal species, also includes a comprehensive knowledge-base on biologic, ecologic, economic, and distributional characteristics of 141 plant species, 13 wildlife species, and one ecosystem. It could be a valuable tool for land managers and planners. A personal computer version is available. Editing to compile a plant and wildlife knowledge base specific to a smaller unit, such as a National Forest, is possible.

INTRODUCTION

This paper describes aspects of the Fire Effects Information System developed by the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, in cooperation with Dr. Alden Wright, University of Montana Computer Science Department. Simply stated, the Fire Effects Information System is a computerized information storage and retrieval system. The particular emphasis of this paper is the vast informational content of the system's knowledge base and the use of vegetation classifications in that knowledge base. The Fire Effects Information System was developed to be an authoritative, easy to access source of information regarding the effect of forest and range fire (both wildfire and prescribed fire) on individual plant and animal species and on the plant communities in which these species reside. To that end, comprehensive information on physiologic, ecologic, distributional, economic, as well as fire effects characteristics, had to be compiled.

Use of the system, therefore, enables fire prescriptions to be based on the best available information and experience regarding the response of target plant species to fire and how this response varies according to such factors as fire severity, season, phenological state, successional status, site characteristics, and other biological

and environmental considerations. Lack of organized, interpreted fire effects information, perceived by many managers as a barrier to the effective use of prescribed fire for vegetation management (Kickert and others 1976; Kilgore and Curtis 1987; Noste and Brown 1981; Taylor and others 1975), is no longer a valid excuse. There is plenty of information about fire effects in general and plant response to fire in particular, especially for the relatively few species of primary management concern.

BRIEF DESCRIPTION OF THE SYSTEM

The Fire Effects Information System is a computerized knowledge management system that stores and retrieves, in textual form, state-of-the-knowledge information organized in an encyclopedic fashion. It is, consequently, unlike most information systems available to natural resource managers and staff specialists. It is not a computerized bibliography (although a computerized bibliography is an important appendage to the system). It is not a numerical database although the system does accommodate numerical data.

For those abreast of computer science trends, the Fire Effects Information System is an object-oriented, frame-based, knowledge-based system implemented in the LISP programming language. The system was developed using concepts, methods, and techniques from the rapidly expanding field of artificial intelligence (AI). The application of AI in the design and structure of the system is described by Fischer and Wright (1987) and will not be repeated here. For a general overview of AI applications in natural resource management see Coulson and others (1987).

The Fire Effects Information System consists of three components: the knowledge base, the query program, and the builder program. The knowledge base represents the system's database. It contains the fire effects and related information that is available to users of the system. The query program allows access to the knowledge base, but does not allow any changes in the knowledge base. It is designed for people who are unskilled in the use of computers. The builder program is used by those who are adding to or editing the knowledge base. The user of the builder program is expected to be familiar with the structure of the knowledge base, and is expected to be skilled in the use of computers.

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THE KNOWLEDGE BASE

The Fire Effects Information System knowledge base is designed to accept information in three major categories: plant species, ecosystems, and wildlife species. The ecosystem category includes three levels of classification: an ecosystem level, a cover type level, and a habitat type or plant community level. For each category and level, the knowledge base contains state-of-knowledge information for various predetermined topics for several subject matter areas. Topics by subject matter area for each of the three categories of information are listed in tables 1-3. The knowledge base will accept information only for the predetermined topics listed in those tables. Addition of other topics is relatively simple for someone who is familiar with the structure of the system and capable of programming in the LISP language. Failure to make an entry in the knowledge base for a given topic has the effect of deleting that topic as far as a user of the query program is concerned. The topic

title will not appear on the screen of the user's computer terminal unless an entry for that topic exists in the knowledge base. Fischer (1987) and Fischer and Wright (1987) provide examples of system output essentially as it would be displayed on the screen of a user's computer terminal.

Knowledge Base Development

The information contained in the knowledge base is the product of a rigorous process that includes (1) a thorough bibliographic search to identify literature related to the topics listed in tables 1-3, (2) obtaining hard copy of all such literature, (3) reading the literature, evaluating its reliability, and summarizing useful information, (4) resolving conflicts, if possible, between contradictory information, and (5) entering the information into the knowledge base. The research team responsible for knowledge base development to date is composed of professional biologists trained in the areas of botany,

Table 1--Plant species information by subject matter area contained in the Fire Effects Information System knowledge base

NOMENCLATURE AND TAXONOMY

Species name
Abbreviation
Synonyms
Common names
Taxonomy
Life form
Compiled by
Last revised by
References

DISTRIBUTION & OCCURRENCE

General distribution
Ecosystems States
Administrative units
BLM physiographic regions
Kuchler plant associations
SAF cover types
Habitat types
References

VALUE AND USE

Wood products value
Importance to livestock & wildlife
Palatability
Food value
Cover value
Value for rehabilitation of disturbed sites
Other uses and values
Management considerations
References

BOTANICAL & ECOLOGICAL CHARACTERISTICS

General botanical characteristics
Growth form
Raunkiaer life form
Grime plant strategy class
Grime regenerative strategy class
Regeneration processes
Site characteristics
Successional status
Seasonal development
References

PLANT ADAPTATIONS TO FIRE

General adaptations to fire
Lyon-Stickney survival strategy
Noble-Slatyer vital attributes
Rowe mode of persistence
References

FIRE EFFECTS

Fire effects on plant
Discussion & qualification
Plant response to fire
Discussion and qualification
References

FIRE CASE STUDY

Case study name
Reference
Season-severity class
Study location
Preburn vegetation
Target species phenological site description
Fire description
Fire effects on target species
Fire management implications

Table 2--Wildlife species information by subject matter area contained in the Fire Effects Information System knowledge base

NOMENCLATURE AND TAXONOMY

Species name
Abbreviation
Common name
Taxonomy
Order
Class
Compiled by
Last revised by
References

DISTRIBUTION & OCCURRENCE

General distribution
Ecosystems
States
Administrative units
BLM physiographic regions
Kuchler plant associations
SAF cover types
Plant communities
References

BIOLOGICAL DATA & HABITAT REQUIREMENTS

Timing of major life history events
Preferred habitat
Cover requirements
Food habits
Predators
References

FIRE EFFECTS & USE

Direct fire effects on animal
Habitat related fire effects
Fire use
References

wildlife biology, range science, and forestry. It takes, on the average, about 5 days for a team member to complete an initial species or ecosystem writeup and enter it into the knowledge base. Following entry into the knowledge base, the information for a given species or ecosystem is reproduced on paper and sent for technical review to scientists, staff specialists, and managers who have expert knowledge of the species or ecosystem. The information in the knowledge base is revised, as necessary, to reflect this technical review. Information in the knowledge base is periodically revised as necessary to incorporate new knowledge from current literature.

At this writing, the knowledge base contains information for 141 plant species (16 trees, 61 shrubs, 47 grasses, and 17 forbs), 13 wildlife species, and 1 ecosystem (sagebrush/grass). The Bureau of Land Management (BLM), U.S. Department of the Interior (USDI) supported development of the prototype knowledge base. A majority of the species included in the current knowledge base are those that frequent the sagebrush, pinyon-juniper, southwestern shrubsteppe, desert shrub, and chaparral-mountain shrub ecosystems described by Garrison and others (1977). Species occurring in other ecosystems and geographic areas can be added as funding allows. Recent cooperation with the National Park Service (NPS), USDI, to build a knowledge base for Wind Cave National Park, South Dakota, has resulted in addition of species occurring in the plains grasslands and Black Hills ponderosa pine forests of South Dakota. A list of species currently represented in the Fire Effects Information System knowledge base is included as an appendix to this paper.

Land and Vegetation Classifications

Land and vegetation classifications are important components of the information entered into the Fire Effects Information System knowledge base. Plant and wildlife species are classified according to their occurrence within categories of the following classifications:

BLM Physiographic Regions (Bernard and Brown 1977),
Forest-Range Environmental Study (FRES) ecosystems (Garrison and others 1977),
Kuchler Potential Natural Vegetation Types (Kuchler 1964),
Society of American Foresters (SAF) Forest Cover Types of the United States and Canada (Eyre 1980), and habitat types and plant community types.

Ecosystems included in the knowledge base will be those described in the Forest-Range Environmental Study (Garrison and others 1977). These soil-vegetation units represent aggregations of Kuchler's potential natural vegetation types. Ecosystem cover types are SAF cover types for forest ecosystems; shrub and grass cover types are designated according to dominant or codominant species. At the plant community or habitat type level, information is added to the knowledge base only when it differs significantly from similar information at the cover type level. Information at the plant community level may be for either individual habitat types or groups of habitat types that share common characteristics and have similar fire response.

Table 3--Ecosystem information by level and subject matter area contained in Fire Effects Information System knowledge base

ECOSYSTEM LEVEL

Ecosystem name
 Classification key
 FRES number
 Kuchler vegetation types
 Ecosystem distribution
 References

PRODUCTIVITY

Characteristics/productivity classes
 Dominant species/productivity classes
 Potential production
 References

CONDITION & TREND

Characteristics of condition classes
 Indicators of trend
 Qualification & discussion
 References

FIRE ECOLOGY & EFFECTS

Fuels, flammability, & fire occurrence
 General fire effects
 References

COVER TYPE LEVEL

Cover type
 Abbreviation
 Classification key
 Distribution
 Site characteristics
 Vegetative composition
 Successional trends
 References

VALUE & USE

Wood products
 Livestock range
 Wildlife habitat
 Other values and uses
 References

FIRE ECOLOGY & EFFECTS

Fuels, flammability, & fire occurrence
 Immediate fire effects on site
 Initial vegetative response
 Long term vegetative response
 Fire effects on grazing potential
 Fire effects on wildlife habitat & populations
 Fire use potential
 References

PLANT COMMUNITY LEVEL

Community or group name
 Abbreviation
 Description
 Community type composition
 Distribution & occurrence
 Site characteristics
 Vegetative composition
 Indicators of good condition
 Indicators of poor condition
 Productivity
 Successional trends
 References

MANAGEMENT CONSIDERATIONS

Wood products
 Livestock range
 Wildlife habitat
 Other considerations
 References

FIRE EFFECTS

Fuels, flammability, & fire occurrence
 Initial community response
 Long term community response
 Fire effects on grazing potential
 Fire effects on wildlife habitat and populations
 Fire use potential
 References
 Fire case studies

Land and vegetation classifications are included in the knowledge base for several important reasons. Foremost is a simple recognition of the increasing use and reliance of these classifications in wildland management decisions at all levels. Classifications are also used because the descriptive data and interpreted information inherent in the classifications become attached to the classified unit, making repeated description and interpretation unnecessary (Nelson and others 1978). Finally, use of the classifications provides a basis for compiling smaller, special purpose knowledge bases from the

main knowledge base. For example, SAF cover types (by State) could be used to compile a plant and wildlife species knowledge base specific to a National Forest.

Biological and Ecological Classifications

In addition to the land and vegetation classifications listed above, plant species are classified according to:

Growth Form,
 Life Form (Raunkiaer 1934),
 Plant Strategy (Grime 1979),
 Regenerative Strategy (Grime 1979),
 Survival Strategy (Lyon and Stickney 1976),
 Vital Attributes (Noble and Slatyer 1977),
 and
 Mode of Persistence (Rowe 1983).

These classifications, based on biological and ecological attributes, allow certain inferences related to the probable effect of fire on a plant species and subsequent plant species response to fire. While these classifications may provide useful information to those familiar with them, they are included primarily for research in the development of fire effects "expert systems." An expert system is a computer program designed to act as an expert in a particular area of knowledge (Mishkoff 1985). An expert system typically includes a knowledge base that contains both facts and rules of thumb through which the program searches to find a solution to a problem (Stock 1987). For more on expert system technology and an example of a forestry application see Rauscher and Cooney (1986).

CURRENT STATUS OF THE SYSTEM

The Fire Effects Information System, which was developed on a Digital Equipment Corporation (DEC) VAX 750 main frame computer at the University of Montana, now resides on a Data General (DG) MV 4000 computer at the Fire Sciences Laboratory in Missoula, MT. Current work includes such system enhancements as improving query program on-screen prompts, adding a print capability and improving knowledge base search and sort capabilities. Early this year the system was installed on a DG MV10000 computer at the Boise Interagency Fire Center for test and evaluation by BLM District and State Office personnel. In the near future, the system will be installed on a DEC VAX 750, also at Boise, for test and evaluation by NPS personnel. Test and evaluation of the system on one or more National Forests is planned for 1988. These tests and evaluations are of the query program and knowledge base only. The builder program resides only at the University of Montana and at the Intermountain Fire Sciences Laboratory. A personal computer (PC) version of the query program and knowledge base is available but a PC builder program is still being developed.

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APPENDIX

Plant And Animal Species Currently Represented In
The Fire Effects Information System Knowledge Base

Tree Species

Cercocarpus ledifolius, curlleaf
mountain-mahogany
Cercocarpus montanus, true mountain-mahogany
Juniperus occidentalis, western juniper
Juniperus osteosperma, Utah juniper
Juniperus scopulorum, Rocky Mountain juniper
Pinus albicaulis, whitebark pine
Pinus aristata, Rocky Mountain bristlecone
pine
Pinus balfouriana, foxtail pine
Pinus edulis, pinyon
Pinus flexilis, limber pine

Pinus longaeva, Great Basin bristlecone pine
Prunus monophylla, singleleaf pinyon
Prunus americana, American Plum
Prunus pennsylvanica, pin cherry
Prunus virginiana, chokecherry
Rhus glabra, smooth sumac

Shrub Species

Amelanchier alnifolia, Saskatoon serviceberry
Amelanchier utahensis, Utah serviceberry
Artemisia arbuscula ssp. arbuscula, gray low
sagebrush
Artemisia arbuscula ssp. thermopola,
hotsprings sagebrush
Artemisia argillosa, coaltown sagebrush
Artemisia bigelovii, Bigelow sagebrush
Artemisia cana ssp. viscidula, mountain silver
sagebrush
Artemisia cana ssp. bolanderi, Bolander silver
sagebrush
Artemisia cana ssp. cana, plains silver
sagebrush
Artemisia filifolia, sandsage or sand
sagebrush
Artemisia frigida, fringed sagebrush
Artemisia longiloba, early or alkali sagebrush
Artemisia nova, black sagebrush
Artemisia papposa, fuzzy sagebrush
Artemisia pedatifida, birdfoot sagebrush
Artemisia pygmaea, pygmy sagebrush
Artemisia rigida, stiff or scabland sagebrush
Artemisia spinescens, budsage or bud sagebrush
Artemisia tridentata ssp. tridentata, basin
big sagebrush
Artemisia tridentata ssp. vaseyana, mountain
big sagebrush
Artemisia tridentata ssp. wyomingensis,
Wyoming big sagebrush
Artemisia tripartita ssp. rupicola, Wyoming
threetip sagebrush
Artemisia tripartita ssp. tripartita, tall
threetip sagebrush
Atriplex canescens, four-wing saltbrush
Atriplex confertifolia, shadscale
Atriplex gardneri, saltsage
Ceratoides lanata, winterfat
Chrysothamnus nauseosus, grey rabbitbrush
Chrysothamnus viscidiflorus, green rabbitbrush
Cowania mexicana ssp. stansburiana, Stansbury
cliffrose

Ephedra nevadensis, Nevada ephedra
Ephedra viridis, green ephedra
Grayia brandegei, spineless hopsage
Grayia spinosa, spiny hopsage
Gutierrezia sarothrae, broom snakeweed
Holidiscus discolor, oceanspray
Holidiscus dumosus, bush oceanspray
Opuntia polyacantha, plains prickly pear
Potentilla fruticosa, shrubby cinquefoil
Potentilla newberryi, cinquefoil
Prunus andersoni, desert peach
Purshia glandulosa, desert bitterbrush
Purshia tridentata, antelope bitterbrush
Rhus aromatica, fragrant sumac
Rhus trilobata, skunkbrush sumac
Ribes americanum, American black currant
Ribes aureum, golden currant
Ribes cereum, wax currant

Ribes lacustre, swamp currant
Ribes montigenum, gooseberry currant
Ribes odoratum, buffalo currant
Ribes setosum, bristley currant
Ribes velutinum, desert gooseberry
Sarcobatus baileyi, Bailey greasewood
Sarcobatus vermiculatus, black greasewood
Symphoricarpos longiflorus, Longfellow
 snowberry

Symphoricarpos oreophilus, mountain snowberry
Tetradymia canescens, spineless horsebrush
Tetradymia glabrata, littleleaf horsebrush
Tetradymia nuttallii, Nuttall horsebrush
Tetradymia spinosa, spiny horsebrush

Graminoid Species

Aristida purpurea (A. longiseta), three-awn
 grass
Bouteloua curtipendula, sideoats grama
Bouteloua eriopoda, black grama
Bouteloua gracilis, blue grama
Bouteloua hirsuta, hairy grama
Bromus carinatus, California brome
Bromus inermis, smooth brome
Bromus japonicus, Japanese brome
Bromus marginatus, mountain brome
Bromus mollis, soft chess
Bromus rubens, red brome
Bromus tectorum, cheatgrass or downy brome
Buchloe dactyloides, buffalograss
Danthonia intermedia, timber oatgrass
Danthonia spicata, poverty oatgrass
Danthonia unispicata, onespike oatgrass
Elymus canadensis, Canada wildrye
Elymus elymoides, (Sitanion hystris),
 bottlebrush squirreltail
Elymus glaucus, (E. virescens), blue wildrye
Elymus lanceolatus, (Agropyron dasystachyum,
A. elmeri, A. riparium), thickspike
 wheatgrass
Festuca idahoensis, Idaho fescue
Festuca scabrella, rough fescue
Festuca thurberi, Thurber fescue
Hilaria jamesii, big galleta
Hilaria rigida, galleta
Koeleria cristata, prairie junegrass
Leucopoa kingii, spike fescue
Leymus (Elymus) ambiguus, Colorado wildrye
Leymus (Elymus) cinereus, basin wildrye
Leymus (Elymus) salinus, Salina wildrye

Oryzopsis hymenoides, Indian ricegrass
Pascopyrum (Agropyron) smithii, western
 wheatgrass
Poa cusickii, Cusick bluegrass
Poa arida, plains bluegrass
Poa fendleriana, mutton bluegrass
Poa secunda, (P. ampla, P. canbyi, P.
juncifolia, P. nevadensis, P. sandbergii),
 Sandberg bluegrass
Psathyrostachys juncea (Elymus junceus),
 Russian wildrye
Pseudoroegneria spicata (Agropyron spicatum,

A. inermis), bluebunch wheatgrass
Stipa comata, needle-and-thread grass
Stipa columbiana, Columbia needlegrass
Stipa lettermanii, Letterman needlegrass
Stipa thurberiana, Thurber needlegrass
Stipa viridula, green needlegrass
Taeniatherum caput-medusae, medusahead
Vulpia (Festuca) microstachys, small fescue
Vulpia myuros (Festuca megalura), foxtail
 fescue
Vulpia (Festuca) octoflora, six-weeks fescue

Forb Species

Achillea millefolium, common yarrow
Artemisa abrotanum, oldman sagebrush, oldman
 wormwood
Artemisa campestris, sagewort wormwood,
 western sagebrush
Artemisia dracunculus, tarragon
Artemisia ludoviciana, Louisiana sagewort
Balsamorhiza hookeri, hairy balsamroot
Balsamorhiza sagitata, arrowleaf balsamroot
Centaurea diffusa, tumble knapweed
Centaurea maculosa, spotted knapweed
Centaurea solstitialis, yellow starthistle
Descurainia pinnata, tansymustard
Descurainia sophia, flixweed tansymustard
Potentilla glandulosa, sticky cinquefoil
Potentilla hippiana, horse cinquefoil
Ranunculus glaberrimus, sagebrush buttercup
Sisymbrium altissimum, tumble mustard
Sisymbrium linifolium, flaxleaf plains mustard

Wildlife Species

Amphibians & Reptiles

Ambystoma macrodactylum ssp. krausei, northern
 long-toed salamander
Crotalus viridis, western rattlesnake
Sceloporus graciosus, sagebrush lizard
Scophiopus intermontanus, Great Basin
 spadefoot toad

Birds

Aquila chrysaetos, golden eagle
Athene cunicularia, Burrowing owl
Buteo regalis, ferruginous hawk
Centrocercus urophasianus, Sage grouse
Falco mexicanus, prairie falcon

Mammals

Antilocapra americana, pronghorn antelope
Lepus californicus, black-tailed jack rabbit
Perognathus parvus, Great Basin pocket mouse
Spermophilus townsendii, Townsend's ground
 squirrel

GIS DATABASE DESIGN FOR INDUSTRIAL FOREST MANAGEMENT

Dennis L. Murphy

ABSTRACT: Industrial forest management requires accurate map and attribute information to support timber management. Geographic information system (GIS) technology integrates the storage, retrieval, and analysis of both map and attribute data. Database design methodologies structure data in order to model the activities of an organization. A design methodology guides the search for a suitable design. The method (1) identifies critical data, (2) classifies the data into layers, map features, and attributes, and (3) expresses the design in data definition statements. A geographic database design for an in-place forest management inventory provides an example for similar design efforts.

INTRODUCTION

Management of a commercial forest in a highly competitive industry requires the forest manager to respond to changing market conditions. The manager relies upon inventory information to prepare and modify plans and budgets, which guide forest operations. The inventory information describes timber volumes at specific locations. Intensive forest inventories provide the data to support the manager's information requirements. Specifically, the intensive (or in-place) inventory addresses two fundamental forest management questions: "What volume of end products is available for harvest?", and "Where is the volume located?"

The in-place inventories collect tree measurements from which volumes are derived. Timber stands define the sampling unit for the in-place inventory. By delineating these discrete polygons on a base map, the forester not only records the management unit, but also defines the boundaries from which stand area is measured. The stand area expands the inventory sample estimates to total stand estimates of volume. Stand level summaries can be further aggregated to report by larger administrative units.

Effective management of the inventory database to facilitate storage, retrieval, and analysis is necessary in order to realize the potential benefits of the investment. Particularly for forest management organizations with large land holdings, manual record storage methods are no

longer practical. The combination of a digital attribute database with a traditional paper map file is also ineffective. The discipline of geographic information systems provides the technology to effectively manage a forest inventory database consisting of detailed map information and site-specific stand attributes.

An important task in the implementation of a geographic information system is the design of the integrated map and attribute database. As part of the software system, a GIS provides the basic structure for data storage; within the structure, the user designs a database for the specific application.

The design considerations to a new system user are not always evident. Each organization that implements these systems addresses similar design problems. Unfortunately, few system application designers have documented the results of their efforts for the benefit of others. The purpose of this paper is to describe the design of the integrated resource inventory database implemented for Potlatch Corporation, Western Wood Products Division, Lewiston, ID. Although the resulting design is specific to the Potlatch Corporation inventory cruise system and the data model supported by a commercially available GIS, the results have general benefit to other forestry organizations addressing GIS database design issues.

COMPONENTS OF THE IN-PLACE FOREST INVENTORY

Stand Delineation

The timber stand is the primary map feature of the in-place inventory. The following factors are considered in the delineation of a stand:

1. Size: 10-acre minimum (average size is 150 acres).
2. Single management prescription: Can the bounded area be treated by one management prescription?
3. Operability: Is it feasible to complete the prescribed management activity within one planning period?
4. Sampling unit: Is the variability within the boundary relatively small?

Note that the phototype is not a consideration in stand delineation. In contrast to inventory sample designs based upon a stratification of vegetation types delineated from aerial photography, the in-place cruise defines each individual stand as a separate sample unit. The stand may contain a single phototype but frequently is a collection of similar phototypes. The stands

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delineated under an in-place inventory system tend to be larger than the stands mapped from an inventory designed with a stratified sample of vegetation phototypes.

Other map features that influence stand delineation include public land survey lines, ridges, streams, and roads. Public land survey defines the ownership for the organization. All stands are contained within the mapped ownership. The accuracy of the ownership can significantly alter the stand acres estimate. Planimetric features (ridge lines, streams, and roads) are also frequently used as boundaries between stands. The planimetric features represent breaks in terrain conditions.

The forester assigns a unique number to the delineated stand. The unique identifier is an hierarchical key--the key identifies three spatially nested administrative units: logging unit, management block, and stand.

Stand Attributes

Within the stand boundary, an intensive cruise establishes plot locations at an average density of one plot per five acres. Tree measurements are collected at the plot locations. Field personnel record stand level characteristics and assign management prescriptions as part of the cruise procedure.

The tree measurements collected from the plots within each stand are the source for stand tables specific to the stand polygon. The stand table is a tabulation of trees per acre by species and diameter class. From the stand table characteristics, average volumes per acre are estimated for

end products using current log merchandising specifications. The merchandised stand tables are further summarized to derive stand level attributes.

The map features and the stand level attributes are managed as an integrated resource inventory database. A GIS integrates the database components into a single system. In order to manage this dynamic database, the data elements have been structured using a GIS data model described in the section below.

DATA MODEL

The ARC/INFO GIS software (ESRI 1987) incorporates a topological-relational data model. The data model components include map layers, map feature tables, attribute tables, and relationships between them (fig. 1). Map layers are stored as groups of data files containing the coordinate data for the map features. Two types of tables are available in the model to store attribute data: map feature tables and attribute tables. The software creates map feature tables when the map layer data files are processed by edit utilities. Depending upon the type of map feature stored in the map layer, different attributes are automatically included. Map feature types are polygon, line (arc), and point.

A polygon layer always includes a polygon feature table, which stores the area and perimeter of the polygon. At the user's discretion, the polygon layer may also create an arc feature table. The arc feature table can be used to classify the lines which define the polygon boundaries.

An arc layer includes an arc feature table, which stores the length of each arc in the file.

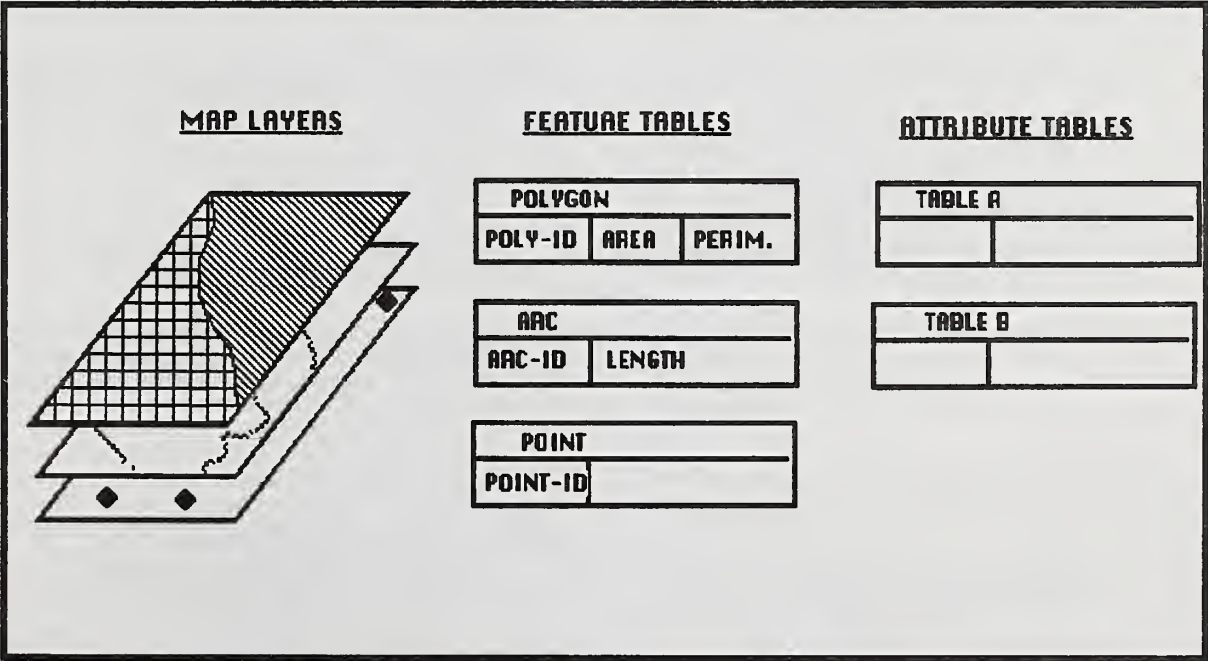


Figure 1--Topological-relational data model.

Point feature tables are created when a point layer is processed. No spatial attributes are stored in the point feature table.

All feature tables store internal identifiers assigned by the software to relate the tables to the spatial (coordinate) data. At the user's discretion, additional attributes may be defined and stored in the feature tables.

The user's database design may also include attribute tables, which are stored separately from the map feature tables. Through the use of a common item, the feature tables may be directly related to the attribute tables and thereby indirectly link the attribute tables to the map features for retrieval and display. Separating the attributes from the feature tables reduces redundant data storage and facilitates the update of map and attribute data as separate system processes.

Data Model Definition

To describe the database design, a data model syntax will be employed to define the database structure implemented for the in-place forest inventory. The definition statements will follow the convention described below:

```
[LAYER] <TABLE:ATTRIBUTE(KEY | RELATE ITEM |  
CLASS/CLASS VALUES/);>
```

Layer is the name of the collection of files storing map features. The layer name is enclosed by brackets.

Each layer has at least one table stored in a relational database management system. The table name follows the symbol "<". By convention, the map feature tables for the a layer are named polygon, arc, or point, depending upon the feature type of the map layer. The attribute names contained in the table follow the colon.

Attributes may be designated in the definition as a key, a relate item, a class item, or the attribute may have no special designation. The specially designated items are identified in the database definition with the appropriate word contained within parentheses following the attribute name, for example, STAND(KEY).

A key attribute uniquely identifies attributes for a specific map feature. By adding a key item to a map feature table, the user provides a link to other attribute tables for retrieval, reporting, and display functions.

A relate attribute also relates records in other tables with the same value for the common attribute between the tables; it is differentiated from a key attribute because the related attributes are not unique for the map feature. Other map features share the same value of the attribute, in contrast to the key which uniquely identifies the attributes for one map feature.

A class attribute can be stored in a feature table to distinguish between categories of map features

stored in the same map layer. For example, road classes are stored in a map layer; a class attribute records the appropriate category for each road segment. One application of the class attribute is the assignment of cartographic symbols for map display.

In the definition syntax, the possible class values appear between slashes, "/". The definition of an attribute table terminates with the right caret symbol, ">".

The database definition statements for the in-place forest inventory are listed below.

Forest Layer

```
[FOREST] <POLYGON:STAND(KEY);AREA;PERIMETER>
```

```
<ARC:ARC-ID(CLASS/LOGGING UNIT/MANAGEMENT  
BLOCK/STAND);LENGTH>
```

```
<MANAGE:STAND(KEY);TREATMENT;PRIORITY;  
HARVEST PLAN STATUS;PERCENT OF  
STAND TREATED>
```

```
<SITE:STAND(KEY);HABITAT TYPE;PHYSICAL  
SITE INDEX;TREE SITE INDEX;  
PHOTOTYPE;AGE STRUCTURE;DOMINANT  
AGE;SECONDARY AGE;ELEVATION;SLOPE;  
ASPECT;SOIL DEPTH;SOIL TEXTURE>
```

```
<VOLUME:STAND(KEY);GROSS SAWLOG;TOTAL NET  
SAWLOG;STEMS PER ACRE;CROWN RATIO;  
QUADRATIC MEAN DIAMETER;BASAL AREA;  
CROWN COMPETITION FACTOR>
```

The primary map feature of the in-place inventory is the stand; the stand is uniquely identified with an attribute that is a concatenated key. The map layer actually contains three administrative units that are nested polygons: logging units (approximately 15,000 acres each), management blocks (1,000-2,000 acres), and stand (average size 150 acres). Since the administrative units represent a spatial hierarchy, all three are represented by the concatenated key stored as a key attribute named STAND.

The key is stored in the polygon feature table and also in the stand attribute tables MANAGE, SITE, and VOLUME.

The stand layer also has an arc feature table; the attribute ARC-ID is a class attribute which identifies polygon boundaries by the management unit they define.

Legal Parcel Layer

```
[PARCEL] <POLYGON:PARCEL-ID(KEY);DEED  
NUMBER(RELATE ITEM);OWNER(CLASS/  
POTLATCH/U.S. FOREST SERVICE/  
BUREAU OF LAND MANAGEMENT/IDAHO  
DEPARTMENT OF LANDS/PRIVATE);AREA;  
PERIMETER>
```

```
<ARC:ARC-ID(CLASS/TOWNSHIP/SECTION/  
INTERIOR LINE);LENGTH>
```

Land ownership defines external stand boundaries. No stand crosses an ownership boundary. The legal parcel layer contains the individual parcels recorded by deed as a land transaction. The polygon table incorporates a unique key for each parcel. Similar to the stand, the legal parcel is a concatenated key representing a hierarchy of nested public land survey polygons: township, section, and legal parcel. A deed number, stored in the POLYGON feature table, serves as a relate item to a land record database (these additional attribute tables are not further described because they are not directly a part of the in-place inventory). A class attribute, OWNER, identifies the current land owner of the parcel.

An arc feature table uses a class attribute, ARC-ID, to distinguish between the township, section, and parcel boundaries.

Baseline Layer

```
[BASELINE] <ARC:ARC-ID(CLASS/RIDGE/CLIFF/DOUBLE
LINE HYDROLOGY/MAJOR STREAM/MINOR
STREAM/LAKE);LENGTH>
```

Streams, rivers, and ridges contribute to the delineation of stand boundaries. These features are stored as arcs with a feature table that has a class attribute (ARC-ID). The class attribute differentiates the linear features stored in the layer; in addition, map symbology assigned for display and plotting references the values of the class attribute.

Road Layer

```
[ROAD] <ARC:ARC-ID(CLASS/PAVED/PRIMARY/
SECONDARY/TRAIL);LENGTH>
```

The road layer has one feature table with a class attribute for different types of roads. The roads are obviously the transportation network for the forest; they also frequently define a portion of the stand boundary.

Basepoint Layer

```
[BASEPOINT] <POINT:POINT-ID(CLASS/STATE PLANE
TIC/PEAK/SADDLE/SURVEY CORNER)>
```

The basepoint layer contains essential features for locational reference and for the development of all other map layers. The POINT feature table includes a class attribute that distinguishes the different types of point features stored in the map layer. The state plane coordinate system grid tic locations were the geographic reference for all map layers. Every map feature was registered to the Idaho State Plane coordinate system. These point features are stored in the BASEPOINT layer. Survey corners are also included in the layer. While the state plane tic marks provide the projected coordinate reference for the map database, the survey corners define the reference points for the public land survey and the legal parcels.

Legal parcels are referenced by public land survey descriptions, as well as coordinate descriptions. Both referencing conventions are essential to the map database.

Other Layers

Applications of the system have and will involve other map layers. Historical information tracking silvicultural and harvest activities is an example. However, this paper limits the discussion to the basic map layers essential to maintain the in-place forest inventory.

RETRIEVAL/ANALYSIS

The integrated storage of the map and attribute data facilitates data retrieval, reporting, and map display. Stands can be selected and displayed with selection criteria based on any of the attributes stored in the tables. The relationship established by the key attribute provides the mechanism. For example, the following selections are possible combining attribute selection criteria from several tables:

1. Map stands that are in a current harvest plan, dominant age greater than 80 years, and net sawlog volume exceeds 5 million board feet per acre.
2. Report total stand volume, stand acres, and harvest priority for the selected stands.

Derived Layers

Spatial relationships within and between map layers provide an analytical capability of the integrated database. The spatial relationships derive new map layers with feature tables containing the attributes of the original map layer feature tables. Spatial analysis functions include: combining map layers, creating buffer zones, and proximity (distance) functions. Polygon map layers can be combined as the union, intersection, or complement of two layers. Also, line and polygon overlays, as well as point in polygon overlays, create new map layers. Proximity functions measure the nearness of a map feature to a second type of map feature.

For example, the analytical capabilities can estimate the area of stands impacted by riparian zone management constraints. The steps and layers derived are summarized below:

1. Select Class I streams and generate a buffer zone of a specified width from the stream centerline. The derived layer is described as follows.

```
[BUFFER] <POLYGON:ZONE(CLASS/INSIDE BUFFER/OUTSIDE
BUFFER/);AREA;PERIMETER>
```

2. Create the union of the FOREST and BUFFER layers, deriving the layer STAND-ZONE.

[STAND-ZONE] <POLYGON:STAND(KEY);ZONE(CLASS/INSIDE
BUFFER;OUTSIDE BUFFER);AREA;PERIMETER>

The layer named STAND-ZONE contains the information in the feature table to summarize the acres by stand within the buffer zone. Note also that as a result of the map overlay, the key attribute (STAND) is included in the POLYGON feature table for the derived layer. Thus, all attributes in the tables SITE, MANAGE, and VOLUME automatically have a relationship to the STAND-ZONE POLYGON feature table through the key attribute. The stand per-acre estimates of volume can be expanded by the acres in the buffer zone to estimate the volume impacted by the riparian zone management.

At the user's option, the derived layers may be added to the database as a permanent layer or further processed with analysis functions.

IMPLICATIONS FOR HABITAT MAPPING

The growth of GIS technology has been accompanied by the expansion of Federal and State programs, which produce digital geographic data for a variety of users. The U.S. Geological Survey's digital files of elevation (digital elevation models), map features (digital line graphs), and satellite imagery are examples. The USDA Soil Conservation Service is digitizing soil type maps. The potential exists to produce and distribute land classification data in digital form to a variety of resource management organizations.

Application of habitat classification methods produces maps and tables of attributes for discrete polygons. GIS technology, the ability to integrate map and attribute data, has potential applications to the management of data for land classifications. How might this information be structured in a geographic database? Two alternatives can be represented as database design options, employing the data definition syntax applied above to the in-place forest inventory.

The first alternative is to manage a database of habitat maps and attribute tables. The GIS could then be used to manage the data and produce either paper products or digital files for users of the information. The layer is described as follows:

[HABITAT] <POLYGON:HABITAT-TYPE(RELATE ITEM);
AREA;PERIMETER>

<CHARACTERISTICS:HABITAT-TYPE;
ATTRIBUTE1..ATTRIBUTEEn>

A second alternative is to maintain a database of source information from which habitat type maps would be derived. The analytical functions of the geographic information system would be applied in this alternative to derive the habitat types based upon spatial relationships between the source map layers. An example of a database structured in this fashion is as follows:

[LAND COVER] <POLYGON:VEGETATION(RELATE ITEM);
AREA;PERIMETER>

<COVER-TYPE:VEGETATION;ATTRIBUTE1..
ATTRIBUTEEn>

[ELEVATION] <POINT:ELEVATION>

[SLOPE] <POLYGON:SLOPE-CODE(CLASS)/CLASS1..
CLASSn;/AREA;PERIMETER>

[ASPECT] <POLYGON:ASPECT-CODE(CLASS)/CLASS1..
CLASSn;/AREA;PERIMETER>

[SOIL] <POLYGON:SOIL-CODE(RELATE ITEM);
AREA;PERIMETER>

<SOIL-TYPE:SOIL-CODE;ATTRIBUTE1..
ATTRIBUTEEn>

As a point layer, elevation can be manipulated to produce the slope and aspect layers specifying the class intervals at the time the layers are derived. In addition, elevation point data can be modified to produce a polygon layer of elevation, with elevation intervals specified by the user. A union of the five polygon layers (elevation, slope, aspect, land cover, and soils) would result in a map layer of polygons, which represent the lowest common denominator between the original map layers.

The second database design alternative has major benefits if the individual map layers can be developed. The user has more flexibility with the separate map layers. If one layer changes due to new information, the new layer replaces the old. The derived habitat layer can be reprocessed. An example is the replacement of a general soil survey by a higher resolution survey not previously available. The derived habitat layer can be recreated using the new soils layer. In addition, the multi-layer approach provides the end data user with the capability to customize the derived layer by specifying the classification "rules" to follow.

By maintaining the original resolution of the map layers and attributes, alternative habitat type layers can be derived for organizations with differing resource management objectives. If the original database design takes full advantage of the data model to specify map feature keys, relate attributes, and class attributes, the system can provide the flexibility to produce map and tabular reports from the source data to satisfy a variety of users with requirements specific to their organization.

CONCLUSIONS

The in-place inventory represents a substantial investment by a forestry organization. The level of effort to collect the information is not justifiable if the end product is single map and corresponding table. The benefit of an integrated geographic database is the expanded capability to derive map and tabular products from the relationships established by the data model or derived from analytical functions applied to the model. With the proper design effort, the database can be updated to meet operations requirements for current data.

In a similar manner, land classification studies represent a substantial data collection and analysis effort. Intensive field data collection techniques result in maps and attributes describing land characteristics. The utility of this information would be extended by developing an integrated geographic database designed with fundamental map layers, feature tables, and attribute tables. By designing the database with the objective of deriving the land classification from source layers, the database will provide more flexibility for resource managers to derive digital and paper products customized for their specific requirements. In addition, the database design will accommodate changes in source map layers when information of higher quality becomes available.

The technology is available to manage integrated resource databases of map and attribute information. Land classification research and applications produce both map and tabular data. The utility of this information can be extended with today's geographic information system technology.

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HABITAT TYPES ARE A TOOL FOR PRESCRIBING STAND TREATMENT

Milo J. Larson

ABSTRACT: Habitat types provide silviculturists an improved basis for prescribing stand treatments. The method is widely accepted and its advantages include ease of application and much-improved results from silvicultural applications.

INTRODUCTION

Habitat types are the land area that will support an identifiable plant association once plant succession progresses to its latest stages. They are usually identified in the field by key indicator plants that are present in the life of a stand (Daubenmire and Daubenmire 1968).

Habitat types have filled an information gap that has heretofore been met by a trial-and-error process known as experience. Silvicultural experience was extremely localized and the opportunity to learn from others in other areas was hampered by glaring inconsistencies in results that could not be readily explained.

The major advantage of habitat types is that they reflect a range of environmental conditions. This range is much narrower than the range of conditions identified with an individual tree species or cover type. Consequently, silvicultural implications for a given treatment can be much more closely refined than ever before.

When a habitat type (or plant association) classification is completed for an area, every acre of the forest can be readily identified to a set of environmental conditions. The individual types are readily identifiable so that they can be recognized by virtually any trained individual without special equipment or an advanced education. Even without a substantial mapping effort, useful conclusions about any given stand can readily be reached.

USE IN SILVICULTURE

Some basic silvicultural applications that are important include reforestation, harvest prescriptions, assessing site quality, rating pest susceptibility, choice of tree species to favor in management, and prediction of plant communities

that will result from the application of a treatment. The number of ways habitat types can be used to improve silvicultural decision making is almost infinite, and is limited only by the intuition of the individual making the prescription.

The major advantage lies in providing a framework for the experience and insight we already have to a stand that lies somewhere in the range of environments occupied by the species being managed. Examples may illustrate:

Lodgepole pine (*Pinus contorta*) grows on more than 100 habitat types (Alexander 1985); a small list of about 10 or so may occur on a Ranger District where lodgepole occurs. What do the habitat types tell us that lodgepole pine types or community type do not? Consider lodgepole pine growing on a warm moist habitat type such as western redcedar/pachistima (*Thuja plicata*/*Pachistima myrsinites*). The silvicultural implications include a relatively good site, a relatively short pathological rotation for lodgepole pine, a variety of associated species that can be grown there, and a good potential for luxuriant shrub or forb stands following disturbance.

In the same general area, a lodgepole pine stand may grow on a cold, moist habitat type such as mountain hemlock/rusty menziesia (*Tsuga mertensiana*/*Menziesia ferruginea*) habitat type. In this stand, site index will probably be lower, the list of associated species will be much shorter and include plant and animal species not common on the warmer habitat type. Regeneration problems associated with snow mold, snow bend, cold nights, and short summers also come to mind.

The difference in response of both plants and animals to a given treatment such as a clearcut will be dramatic on these moist but very different sites.

REGENERATION

An early and perhaps the most crucial application of habitat types was in reforestation prescriptions. Several aspects of regeneration of tree stands have been improved.

Successional Status

Recognition of the successional status of tree species within a habitat type greatly improved reforestation success. Before habitat types came along in the late 1960's, foresters typically planted the species that were cut. For example,

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Douglas-fir (Pseudotsuga menziesii) and grand fir (Abies grandis) stands were clearcut and replanted. They often failed to do well on habitat types where ponderosa pine (Pinus ponderosa) or lodgepole pine would have clearly been better performers in early seral stages. This has been attributed to near-the-ground frost or day-to-night temperature extremes (Larson 1977). Errors were also made at the other end of the ecological scale such as when ponderosa pine was observed to grow well on many sites where grand fir or white fir (Abies concolor) grew. Thus, the assumption was made that it would do well every place white fir or grand fir grew. Many failures resulted because some habitat types that support grand fir or white fir are too cold for ponderosa pine to grow well even though many of the warmer fir habitat types are very favorable.

Probability of Seedling Survival

The plants that grow on the various habitat types indicate the range of environmental conditions from warm to cold and dry to wet. The coldest, the warmest, the wettest, and the driest habitat types are often easily recognized and can be predicted to be difficult for seedling establishment regardless of successional status of the species chosen. These simple observations can and should influence choice of regeneration method or even the suitability of land for production of timber.

Natural Regeneration

The most complex and interesting aspect of habitat types is that choice of regeneration method and degree of canopy opening control, to a large extent, the species composition of the new stand. It varies by habitat type but is predictable with a reasonable degree of reliability for a given area (USDA Forest Service 1985). One brief example is the subalpine fir/twin flower (Abies lasiocarpa/Linnaea borealis) habitat type. On this and similar habitat types, selection and light multistep shelterwood cuts favor subalpine fir (Abies lasiocarpa), two cut shelterwoods with a heavy seed cut tend to favor Engelmann spruce (Picea engelmannii) or lodgepole pine. These rather profound effects are often overlooked by silviculturists, managers, forest planning models, and the general public, all of whom may expect that spruce regeneration will result regardless of the regeneration method chosen.

The dozens of species, hundreds of habitat types and response to the various silvicultural systems are the heart and soul of silvicultural expertise in areas where natural regeneration is the desired goal.

Competing Vegetation

Lack of knowledge of response of nontree vegetation has caused some expensive and serious errors in reforestation.

For example, there are a large number of forest habitat types with understories of shade-loving

forbs. These plants typically perish upon stand opening and the more seriously competitive grasses and sedges invade over a several year period. Prompt reforestation without substantial site preparation is the best choice on these sites. Other habitat types have understories comprised of intensively competitive shrubs, grasses, or sedges that respond vigorously and promptly to stand opening. Here the prescriptions must provide for adequate site preparation.

Choice of site preparation should also be influenced by the habitat type. For example, burning is a good site preparation method on many habitat types, but on several it does not favor regeneration of conifers, notably those with oak (Quercus spp.) understory unions and high-elevation subalpine fir habitat types (USDA Forest Service 1986).

Knowing habitat type in advance of the timber harvest is the key to avoiding unnecessary problems or expense.

PEST MANAGEMENT

Because habitat types can be used to predict environment, they sometimes can be used to predict a range of conditions adverse or favorable to a certain pest. An example is that some habitat types that support host tree species for western spruce budworm are too cold to support epidemic outbreaks of the insect.

Although many relationships between habitat types and pest populations probably exist, a great deal more research will be necessary to identify them.

Site Quality

Habitat type is the primary variable for predicting productivity in the Stand Prognosis Model (Stage 1973). It is also used for estimating site quality in silvicultural decision making (Steele and others 1983). Each habitat type reflects a range of site qualities. The range for some habitat types is very broad and for others quite narrow. The ones most critical in designing timber sales or silvicultural projects are those habitat types with narrow ranges of site quality that are either very high or very low.

Stockability

The concept of limited stockability has been applied to habitat types near the environmental extremes for tree growth (Steele and others 1983). Even though the trees attain good size and reflect a fair site index, the stands are not capable of supporting full or normal stocking.

NONTIMBER RESOURCES

Management objectives often favor forage, browse or other nontree vegetation. Knowledge of habitat types is essential to predict the response of the desired vegetation. In support of that view, the most confusing conference I ever attended

concerned the effects of fire on ponderosa pine. One speaker had burned and obtained delightful stands of grass, another all the shrubs and browse anyone could ever want, another got lots of little pine trees, yet another was keeping little white fir trees out of the type. The only generalization possible was that if one did not know the habitat type, one could not know the effects of fire on ponderosa pine stands or the attribute of the understories one might be trying to enhance.

Forage Production

The quantity and quality of livestock forage in both early and late successional stages are generally predictable for a given habitat type. The estimates are not precise but are helpful in narrowing choices for treatment prescriptions.

Large-scale clearing of woodland types was done in the southwestern United States to improve forage for livestock and it produced mixed results. This was done largely prior to the development of habitat types for the area. Now that retreatment of some of these areas is being considered, habitat types will be useful in assessing potential response (Moir 1986).

Browse Production

Browse production in forest stands is affected by successional status within a habitat type and the nature of the treatment applied as well as the habitat type itself. On a habitat type such as grand fir/pachistima (Abies grandis/Pachistima myrsinites), burning will produce a shrub community comprised of palatable species, while mechanical clearing will produce a herbaceous and low shrub community with little browse (Daubenmire and Daubenmire 1968). On a ponderosa pine/Arizona fescue (Pinus ponderosa/Festuca arizonica) habitat type, neither treatment will produce a significant amount of browse (USDA Forest Service 1986).

Although the number of relationships may be very large, it is clear that getting the most out of prescriptions for browse production requires knowledge of habitat types.

LIMITATIONS

Habitat types are a powerful tool in silviculture, but they are limited in several ways. Each reflects a range of conditions, consequently potential responses are not as predictable as we would like to think they are. They reflect some factors affecting tree stands but by no means all. Thus they are not a substitute for soil surveys and other classifications that convey additional information. The multiple pathways in plant succession are influenced by macroclimatic events and chance factors that confound the influence of local environments.

In spite of the limitations of the concept, it has profoundly influenced silvicultural practice where it has been used. It can be expected to do so in the future and to find use in additional areas of

the United States and perhaps elsewhere in the world.

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USE OF HABITAT TYPES IN SETTING REFORESTATION

STOCKING STANDARDS IN NORTHERN IDAHO

Arthur C. Zack

ABSTRACT: A northern Idaho National Forest developed site-specific reforestation stocking standards based upon habitat type groups. The standards were developed by local silviculturists relying on a combination of literature reviews, local experience and testing, and growth model verification. There are three parts to each stocking standard: a minimum number of potential crop trees per acre, a minimum percent stocked plots, and a subjective test for distribution of stocked plots. The stocking standards are an integral part of a four-part reforestation monitoring system that includes the standards, instructions for applying the standards, a reforestation examination system, and a computerized data base that tracks reforestation results. The four-part monitoring system provides for consistent evaluation of reforestation results, future refinement of reforestation standards and treatments based upon results, and accountability to managers, the public, and Congress. Basing standards on habitat type links reforestation objectives to the productive capability of the land, provides a link to projected forest plan outputs, and provides a framework for experience of local foresters.

INTRODUCTION

With growing resource demands upon a fixed land base, reforestation has become one of the most critical jobs of the USDA Forest Service. Stocking standards are necessary to determine whether the reforestation job has been adequately performed. In the Inland Northwest, as demands upon the land have grown throughout this century, there has been an evolution of reforestation stocking standards.

The major 1910 fire in northern Idaho put the Forest Service into the reforestation business on a large scale. The success of reforestation efforts had to be evaluated. Seedling counts per unit of land area are undoubtedly one of the oldest methods of evaluating regeneration. However, tree counts fail to address the problem of distribution and become rather expensive as

the number of trees rises. Recognizing this, Lowdermilk (1921), working in Forest Service Northern Region (Montana and northern Idaho), began to use stocking percent of milacre plots as a method of evaluating reforestation success. By 1926, the Regional Forester decided that, for all Forest Service Northern Region reforestation surveys, milacre stocking would be the criterion for evaluating reforestation success, with 40 percent stocking of milacre plots defined as success. Haig (1931) believed that using stocked plot percentages was satisfactory, but that the size of the plot should be the inverse of the number of seedlings per acre necessary for full yields at rotation age. This argument led to Forest Service use of stocked 4-milacre plots in the western white pine type.

Wellner (1940) discussed three methods of evaluating regeneration in use in northern Idaho: number of trees per acre, milacre stocking percent, and 4-milacre stocking percent. He evaluated the three methods, presented data that allowed converting from one method to the other, and made recommendations for desirable stocking levels. Wellner recommended that average minimum satisfactory stocking for the white pine type be set at 1,000 trees per acre, or 65 percent 4-milacre stocking.

In the following decade there were a number of important articles about reforestation surveys and standards (Lynch and Schumacher 1941; Long 1947; Staebler 1949; Allen and others 1951). This interest was probably an outgrowth of the post-Depression, post-war increase in intensity of timber management on public lands. The emphasis was still on the stocked quadrat method of survey (primarily because of its low cost), but tree size, species, seedling condition, and management objectives were also considered.

The next period of strong interest in regeneration standards and surveys was from the mid-1970's up through the mid-1980's (Stage 1974; MacLeod 1977; Stein 1978; Kaltenberg 1978; nine papers on regeneration surveys presented in a technical session at the Society of American Foresters 1983 convention; Ferguson and others 1986). Increased environmental awareness, the visible end of any large amount of harvestable old growth timber in the United States, the ever-intensifying demands upon the forest land base, and concern about a reforestation backlog on National Forest lands were probably all reasons for this renewed interest in reforestation. Awareness of the limitations of stocked plot surveys, combined with increased management

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intensity, brought back into favor those reforestation examination systems that counted and recorded information about individual seedlings. There was renewed discussion of tying reforestation standards and surveys to land productivity and management objectives, and thus to detailed land classification systems rather than broad regional cover types.

In the mid-1970's, the Forest Service became concerned about the reforestation backlog that accumulated during the previous two decades of increasing timber harvests. Congress responded through the National Forest Management Act of 1976 (NFMA). Some of the pertinent NFMA language reads as follows:

It is the policy of the Congress that all forested lands in the National Forest System shall be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stand designed to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans. Accordingly, the Secretary is directed to identify and report to Congress annually . . . the amount and location by forests and States and by productivity class, where practicable, of all lands in the National Forest System where objectives of the land management plans indicate the need to reforest areas that have been cut-over or otherwise denuded or deforested . . . All national forest lands treated from year to year shall be examined after the first and third growing seasons and certified by the Secretary in the report provided under this section as to stocking rate, growth rate in relation to potential and other pertinent measures.

. . . timber will be harvested from National Forest System lands only where . . . there is assurance that such lands can be adequately restocked within five years after harvest . . .

There was now a clearly stated Congressional mandate to maintain forest cover, to reforest the backlog within 10 years, and to spend significant amounts of money to meet these objectives. Appropriate forest cover was defined not just as a stocking rate, as might have been determined from stocked plot percentages. It also included species of trees and rate of growth, was linked to management objectives as defined in forest plans, and was tied to potential productivity. In addition, the Forest Service was directed to examine treated lands at particular times, to report to Congress quite specifically about the status of regeneration, to certify the acceptability of its regeneration according to defined standards, and to refrain from harvesting any land that was not generally capable of being satisfactorily regenerated within 5 years of final harvest.

In late 1984, the Idaho Panhandle National Forests began to develop reforestation stocking standards. Forest Service Northern Region stocking guidelines and regeneration examination formats had been in existence for years. However, both systems were fairly general, and there was great variation in

how they were applied. There was also a regional timber stand data base that had the capability to track reforestation results, but its use for this purpose was scattered and inconsistent. Professional foresters felt the need for site specific, locally applied tools to evaluate reforestation results and learn from past practices. As public interest groups began to raise questions about reforestation results, better standards were needed for both data collection and reforestation evaluation. The Forest Plan, which was also getting close to completion, needed a tie between projected plan outputs and standards for reforestation.

OBJECTIVES

In December of 1984, the Idaho Panhandle National Forests began to develop standards for a reforestation monitoring system that would address the above needs. This reforestation monitoring system had to meet the following objectives:

1. Fulfill NFMA requirements by addressing degree of stocking, species composition, rate of growth, stand conditions, forest plan management objectives, and potential land productivity;
2. Be able to deal with both the density and distribution of stocking;
3. Be flexible enough to apply to the variety of local conditions found across the Forest;
4. Be expressed in terms that the average forestry field worker could reasonably understand, rapidly accept, and easily put into use;
5. Be capable of direct incorporation into a stand prescription;
6. Include a relatively inexpensive, quick, efficient, and reliable survey system to ensure compliance with stocking standards;
7. Be useful in a variety of circumstances for making decisions about the acceptability of regeneration;
8. Be reasonably compatible with existing systems, including the Forest Service Northern Region Stand Exam System and the Timber Stand Data Base; and
9. Be capable of displaying clear results to managers, the public, and Congress.

METHODS

The entire system of stocking standards was developed over a 3-year period. This allowed for taking one piece of the problem at a time, drafting standards, field testing, and making necessary revisions. To utilize local experience and gain local acceptance, the job was carried out by a working group of experienced silviculturists from Ranger Districts across the Forest, the Forest silviculturist and his assistant, and a research forester from the Forest Service, Intermountain Research Station in Moscow, ID.

Each year, the Silviculture staff in the Supervisor's Office of the Idaho Panhandle National Forests wrote to the local Ranger Districts, defining the part of the problem to be considered, nominating silviculturists to help in the effort,

and asking for literature pertinent to the topic. Based on literature reviews, local field experience, experience with the Regeneration Establishment Model (Ferguson and others 1986), and a healthy dose of professional judgment, the group developed a draft standard. The draft standard was reviewed by the forest planning staff, and modified as necessary. Prognosis Model (Stage 1973; Wykoff and others 1982) projections were made to test assumptions in the draft standards. Following review by the entire forest silviculture group, the standard was put into trial practice on all Ranger Districts for one field season.

The next winter, another silviculture working group was assembled. Each year, about half the group would be people from the previous year, and half would be new people. This maintained continuity while gaining diverse skills and perspectives. This was also useful in fostering a broad sense of ownership of the results. The group reviewed the field results and modified the draft standards from the previous year. Then, using the same methodology, the group considered the next piece of the problem. The Idaho Panhandle National Forests' reforestation stocking standards are now available and will be written into the Forest Service Northern Region Reforestation Handbook as a local forest supplement.

REFORESTATION MONITORING SYSTEM

The reforestation stocking standards are the first part of a four-part reforestation monitoring system. The basic format of the system ties the reforestation stocking standards to the productive capability of the individual forest stand. It was decided that the habitat types of northern Idaho (Cooper and others 1987) would be the measure of land capability. Habitat types were utilized for four reasons. Locally, they were the most widely used and easily applied measure of land capability. They provided a link to potential for timber productivity (Cooper and others 1987). They provided a tie to timber outputs in the Forest Plan (USDA 1987). And they provided a framework for local observations about reforestation results and problems.

The reforestation monitoring system consists of four parts:

1. Reforestation stocking standards by habitat type group, with each habitat type group standard specifying a minimum acceptable number of potential crop trees and a minimum percent stocked plots;
2. Instructions for applying the stocking standards;
3. Standards for a regeneration establishment examination to determine if the stocking standard has been met; and
4. Instructions on how the stocking standards, activities to meet those standards, and regeneration examination results will be recorded in the Forest Service Northern Region computerized Timber Stand Data Base.

Reforestation Stocking Standards

Minimum stocking standards for the Idaho Panhandle National Forests are shown in table 1. Habitat type groups--defined as good, medium, and poor sites--are used to index site productivity. Regeneration areas not meeting these standards are candidates for remedial treatments.

Potential crop trees are limited on a plot basis to the equivalent of 900 trees per acre. These trees must be at least 3 feet apart, of good form and vigor, of acceptable species (based on the silvicultural prescription), free to grow, and have no damaging agents that would preclude trees from reaching rotation age without serious volume loss. In addition, natural regeneration must have survived a minimum of two full growing seasons before being counted as potential crop trees. Potential crop trees will be the best trees on the plot that meet these conditions.

Table 1--Minimum stocking standards for the Idaho Panhandle National Forests

Site/habitat type	Potential crop trees per acre	Percent stocked plots*	
		1/300 A.	1/100 A.
Good sites: all cedar and western hemlock series	400	65	80
Medium sites: all grand fir series, best subalpine fir and mtn. hemlock series; ABLA/CACA STAM, CLUN; TSME/CLUN	300	60	80
Poor sites: all others not in above groups; all Douglas-fir series; ABLA/MEFE, VACA, XETE, LUHI, VASC; TSME/MEFE, XETE, LUHI	200	50	70

*A stocked plot is defined as a plot where the tree count of potential crop trees is equal to at least 2/3 the stocking objective for that site. (Example: 1/100 acre plot where 400 trees/acre are required; if there are three trees on the plot, that is 3/4 of stocking objective and the plot is counted as a stocked plot; if there are two trees on the plot, that is only 1/2 of the stocking objective and the plot is not counted as being stocked).

Instructions for Applying Stocking Standards

The Forest Service classifies regenerating stands as certified, progressing, or failed. A certified stand is adequately stocked with well-spaced,

established, suitable, free-to-grow trees, and can be removed from regeneration status. Progressing stands are regenerating at an acceptable rate and are not expected to need any significant further treatment to become adequately stocked. Failed stands will not be adequately stocked within an acceptable time without further treatment.

Certification as adequately stocked is based upon satisfying all parts of a three-part standard. Habitat type is used to properly enter the stocking standards table. For certification, a stand must:

1. Have the minimum number of potential crop trees per acre;
2. Have the minimum percent stocked plots; and
3. Be uniformly stocked based upon a subjective analysis of the distribution of stocked plots. Even when the first two conditions are met, if nonstocked plots are clumped, it is likely that the stand is not satisfactorily stocked, and additional treatment may be necessary.

These are minimum standards only, and are not meant to usurp the responsibility of Forest Service silviculturists to set stocking objectives through individual stand prescriptions. These standards are meant to be applied to sites where timber management is a major objective. The stand prescription may call for different stocking levels as a result of other management objectives or local site conditions. If site conditions or management objectives necessitate a prescription with other stocking objectives, those other objectives and their rationale are documented in the stand prescription included in the stand records. If the stand is certified at less than the minimum standards, the reason for that decision is also documented.

Standards for Regeneration Examination

The examination is used to determine the stocking condition of a regeneration unit. Satisfactory stocking is based upon the stand prescription or the minimum standards shown in table 1.

The examination is an abbreviated version of the standard Forest Service Northern Region stand examination. Plots are located on a randomly placed grid that evenly samples the entire stand. Sample design is such that the 95 percent confidence interval about the mean number of potential crop trees shall be no more than ± 20 percent of the mean, and there shall be at least one plot for every 2 acres. Under common stand conditions, 20 to 30 plots will meet these design objectives.

The examination record includes a topographic map of the stand showing all plot locations, with each plot labeled as either stocked, nonstocked but capable of stocking, or nonstockable. Stocked plots and potential crop trees are as defined in table 1. A plot is defined as nonstockable when over 50 percent of its area is not capable of supporting normally growing conifers.

The examination is based on either 1/100- or 1/300-acre circular plots. All recorded heights and growth rates are estimated. A tally is made of potential crop trees on the plot up to a maximum number equivalent to 900 trees per acre. Potential crop trees are grouped by species and 1-foot height classes, and average height is recorded for each group. Height growth for the last complete year to the nearest 1/10-foot is recorded for each group. A rough estimate is made of the number of trees in excess of full stocking. They are grouped in very broad height classes, and each group is recorded by the species that makes up a plurality of that group. An average height is assigned to each group. If there are serious damaging agents, or potentially competitive vegetation, they are recorded. The inventory normally takes 1 to 5 minutes per plot.

If there is already existing habitat type information for the stand, habitat types are not recorded in the regeneration examination. Any record of habitat type based on examination prior to harvest is likely to be more accurate than a habitat type determination after disturbance.

Data Base Standards

Stand habitat type, site characteristics, prescription stocking objectives in trees per acre, activities on the ground, and regeneration examination results are recorded in the Forest Service Northern Region computerized Timber Stand Data Base. For each regeneration exam, we record potential crop trees per acre and the status of the regeneration (certified, progressing, or failed). Following tree planting, first- and third-year examinations are mandatory. Examinations are repeated until the stand is either certified as adequately stocked according to the minimum standards, or a decision is made and documented to accept a lower level of stocking.

Applications

This system was partially implemented as it was being developed over the last 3 years, and was fully implemented in the fall of 1987. Positive results are already apparent. With clear, site-specific stocking standards, there is a consistent basis for making decisions on whether regenerated stands are adequately stocked or need further treatment. Stocked stands have now been certified as adequately stocked, and are no longer being scheduled for unnecessary examinations. Nonstocked stands that were undetected in previous inventory and tracking systems have now been identified and scheduled for appropriate treatment. Since silviculturists now have a site-specific standard for evaluating success, they also have a basis for learning from the results of their reforestation efforts. A detailed picture of the reforestation situation on the Idaho Panhandle National Forests is now available for land managers and the public. Reports to Congress on reforestation status now include better, and more complete, information.

DISCUSSION

Strengths of the System

The new three-part stocking standards overcome limitations of earlier systems that relied either totally on stocked plot percentages (without any tree information), or relied totally on expensive and time-consuming complete tree inventories. Tallying potential crop trees provides seedling information that helps evaluate regeneration progress. Limiting the number of potential crop trees per plot avoids generating meaningless averages from overstocked plots, and also limits seedling counts to potentially merchantable trees at rotation age. The limitation on potential crop trees tallied also holds down examination time and expense. Including a minimum acceptable percentage stocked plots provides a simple and statistically sound method of evaluating tree distribution. The subjective evaluation of stocked plot distribution overcomes the inability of simple stocked plot percentages to identify clumpy stocking or nonstocked holes in a stand.

Creating the stocking standards within a four-part monitoring system means there is consistency in standards and in how the standards are applied. The whole system provides a measurable, trackable tool for evaluating reforestation success. The system is a useful management tool for silviculturists, provides a public land management agency with accountability to the public and Congress, and can be used to document compliance with the legal requirements of the National Forest Management Act.

The use of a computerized data base for storing both stand and site information plus reforestation results provides a source of data that can be used to refine the stocking standards. This data base also provides a tool for refining reforestation techniques. Data base reports have been developed to sort reforestation results by habitat type, slope, aspect, elevation, or year of planting. Later in the rotation, stand condition, growth, and yield can be compared to initial reforestation results.

Although the stocking standards are created for broad groups of habitat types, stand information is stored in the data base by individual habitat type. This provides the ability to rearrange or split out different habitat type groups as future results dictate.

Tying the standards to habitat types provides some special strengths. Habitat types are a comprehensive measure of the land's vegetative capability; they are currently in common use by northern Idaho forest land managers (Pfister 1980). Habitat type information is available for almost all forest stands that have been inventoried by the Forest Service in this area. Habitat types provide a tie to projected timber outputs because Forest Plan yield tables were built around the same habitat type groups. Silviculturists use habitat types to categorize many of their observations about forest responses. Since the standards were built in large part by local experience, and since habitat types fre-

quently serve as the framework for acquiring new local experience, there is the capability to modify the habitat type specific standards as newly acquired local experience may dictate.

Limitations and Research Needs

The stocking standards have a number of limitations because they are structured by habitat type. Every one of these limitations also points to an avenue that needs further research.

Habitat type classifications are based on potential climax vegetation (Cooper and others 1987). Since the classification scheme does not start from productivity classes, it cannot be assumed that habitat type alone will be a good predictor of productivity. In fact, although both Steele and others (1981) and Pfister and others (1977) show mean productivity levels by habitat type, there are very wide confidence intervals about those means. Cooper and others (1987) limit their productivity information to a table of mean basal areas and site indices by habitat type. Building yield tables by habitat type groups, and then tying reforestation stocking standards to those yields, may be questionable if habitat type is not a good predictor of potential yield.

There may be several successional pathways for a given habitat type (Arno and others 1985). Successional pathways may vary due to plant community composition at the time of disturbance, the type or intensity of disturbance, factor compensation, or chance factors like seed crops and weather. The successional community is the environment for reforestation; the habitat type may simply define the range of the possible successional communities and their end point. A variety of successional communities may indicate a variety of conditions for regeneration. It is by no means obvious that a single reforestation treatment or stocking standard will suffice to meet management objectives for all the successional communities possible within a habitat type. Because reforestation takes place in early seral communities, there is a need for research on successional pathways of northern Idaho habitat types.

The biggest weakness in using habitat types to develop stocking standards comes from factor compensation. Habitat types are essentially bio-indicators of the long-term, total environment. However, different combinations of environmental factors may combine to produce essentially the same climax plant community (Cooper and others 1987). For example, a given habitat type may occur on south slopes where soils are deep and have a high moisture holding capacity. With more droughty soils, the same habitat type may be limited to north slopes or the bottom of drainages. Although the climax plant community may ultimately be the same, it is likely that these two situations might have very different patterns of early stand development. It may be that the further a community is from climax, the more significant factor compensation is in

indicating different environmental conditions for plant growth. There is a need to explore the implications of factor compensation in relation to the use of habitat types as a management tool for early seral stands. It may be that for early seral communities, topographic or edaphic features are a necessary companion of habitat types in defining management alternatives.

CONCLUSIONS

Reforestation stocking standards were developed with separate stocking levels for three habitat type groups in northern Idaho. The standards are based on a combination of literature reviews, local experience and testing, and growth model verification. There are three parts to each stocking standard: a minimum number of potential crop trees per acre, a minimum percent stocked plots, and a subjective test for evaluating distribution of stocked plots.

The stocking standards are an integral part of a four-part reforestation monitoring system. The system includes the stocking standards, instructions for applying the stocking standards, a reforestation examination system to measure compliance with the stocking standards, and a computerized data base for storing and tracking reforestation results over the long term.

The stocking standards are a useful tool to land managers, provide accountability to the public and Congress, provide a link to projected forest plan outputs, and meet the legal requirements of the National Forest Management Act. The structure of the entire reforestation monitoring system provides a framework to further refine both reforestation practices and the stocking standards themselves, based on results of their application.

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ELK HABITAT MANAGEMENT IN THE NORTHWESTERN UNITED STATES

Peter Zager

ABSTRACT: Elk habitat management guidelines are based on habitat potential, habitat effectiveness, and biologists' judgments. Habitat potential addresses the relative availability of security and thermal cover, and forage; it is based on vegetative cover types and structure. Habitat effectiveness evaluates habitat loss due to roads in elk habitat; it is based on road density and cover types.

INTRODUCTION

In the public's eye, the number of animals in a population or specific area is the central issue in most wildlife resource debates. Because the public interest dictates policy and wildlife management depends on public support, population and harvest parameters will continue to be a primary focus of wildlife research and management. That may be acceptable if biologists understand that harvest levels and population status are relative to the quantity and quality of available habitat.

Fortunately, it is clear to most wildlife professionals that wildlife management is simply a byproduct of habitat interrelationships. Habitat has received considerable management and research attention, and it is clear that simply defining the primary habitat requirements of a species--food, water, shelter, and space--is not enough to drive management programs. But identifying and evaluating the factors that influence these requirements is no easy task, partly because many of the species of interest are very adaptable--they use a variety of habitats in various ways. Elk (*Cervus elaphus*) in the northwestern United States are a good example.

Historically, elk ranged from the Atlantic Coast, across the Great Plains, through the Rocky Mountains, and to the California coast, and from Mexico to British Columbia and Alberta (Bryant and Maser 1982). Elk occurred in a variety of habitats that formed a gradient from open habitats with little cover to habitat dominated by

forest with few openings. Habitat productivity, weather, topography, and so forth varied considerably from one region to the next, yet all these areas provided elk with their basic requirements of food, water, and shelter.

Today, elk and their habitat are much more restricted. There is a relatively large core of Rocky Mountain elk and elk habitat, and smaller populations of transplanted Rocky Mountain elk, pockets of Manitoban elk and Tule elk. Roosevelt elk are fairly widespread in western Oregon and Washington, and northern California (Bryant and Maser 1982).

Elk are the premier big game species in Idaho and probably in the western United States. Hunters in Idaho spend approximately 500,000 hunter days, with an estimated value of nearly \$20 million, in pursuit of elk each year. There is also an unmeasured but substantial demand for the opportunity to view and photograph elk. Because of the species' importance, research has focused on elk and their habitat for years. This work has shown that even though elk are widespread geographically, they exhibit definite habitat use patterns that necessarily reflect habitat availability. Such habitat use patterns may be unique to geographic areas. For example, Arizona elk occupying the ponderosa pine (*Pinus ponderosa*) zone have different habitats available to them than northern Idaho elk in the cedar (*Thuja plicata*)/hemlock (*Tsuga heterophylla*) zone or coastal elk in the Sitka spruce (*Picea sitchensis*) zone. But typically, elk habitat use is correlated with plant phenology--they key on succulent forage and new growth for most of the year, and use available cover during the hunting season, and on hot or windy days.

Because of the inherent adaptability of the species and resultant variability in habitat use, it is difficult to develop useful generalizations about elk habitat use. Yet generalizations allow one to develop models that have widespread application--the search for such generalizations is basic to wildlife research. As research evolved and knowledge accumulated, an approach to elk habitat management began to crystalize, leading to a conceptual model of elk habitat that has two facets, Habitat Potential and Habitat Effectiveness. These are the basis for the elk habitat management guidelines developed for different regions throughout the western United States. (e.g., Thomas and others 1979; Leege 1984; Lyon and others 1985).

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HABITAT POTENTIAL

Habitat potential represents elk habitat as perceived by biologists. This perceived elk habitat provides for all the biological needs of elk. Habitat potential does not address the number of animals an area can support; it would be difficult to convert habitat variables to elk numbers because hunting regulations and seasons are the primary population regulator for most elk populations. Habitat potential reflects current environmental conditions and, therefore, is not equivalent to site potential, or habitat type.

The basis of habitat potential is a cover:forage ratio as determined across a large area. This ratio is based on the percentage of an area that qualifies as cover versus that qualifying as forage. The typical habitat potential guideline, derived from work in the Blue Mountains of Washington and Oregon (Black and others 1976; Thomas and others 1979), is a 40:60 cover:forage ratio, that is, 40 percent of the area provides cover and 60 percent of the area is classified as forage areas.

Cover

Cover, or crown cover, is coniferous or deciduous vegetation used by wildlife for security or to ameliorate environmental conditions. Vegetative structure and canopy cover are used to define cover; species composition may be a secondary consideration. Some biologists include all areas with at least 60 percent cover in this category (Wisdom and others 1986).

Biologists further differentiate between hiding or security cover and thermal cover. Black and others (1976) and Thomas and others (1979) reported that 50 percent of the cover should be hiding cover, 25 percent should be thermal cover, and the remaining 25 percent either thermal or security cover, whichever is limiting. Security cover is used by elk to escape from danger; it includes vegetation that hides 90 percent of a standing adult elk at ≤ 200 feet (Thomas and others 1979). The importance of security cover to hunted elk populations is unarguable. Without adequate security cover, elk are quite vulnerable to hunters and hunting seasons must be restrictive. The characteristics of good security cover are open for discussion, however. It is difficult to evaluate security cover because elk are generally able to move from one secure area to another when disturbed. Furthermore, the types of stands that provide security cover necessarily vary as vegetation composition and structure vary, with size of the area, and with topography. In some areas, topography can provide important security cover independent of or in conjunction with vegetative cover and structure. Canfield and others (1986) showed how topography can work against vegetative cover and structure by altering the viewing angle.

Thermal cover ameliorates the effects of weather, reduces travel costs, and provides food sources not available in open areas, such as lichens and

low-growing plants that may be snowcovered during the winter. A coniferous stand >40 feet tall with an average canopy closure of >70 percent is classified as thermal cover for elk (Thomas and others 1979). Multi-storied stands are considered superior because they are typically composed of several different species of different ages and therefore not as vulnerable to catastrophic loss. The importance of thermal cover has been questioned by some biologists. Elk are capable of tolerating temperature extremes, as evidenced by historic and current distribution that includes areas with winter temperatures that are tens of degrees below freezing to hot dry sagebrush or plains habitats (Bryant and Maser 1982). Peek and others (1982) argue that though thermal cover may not be a requisite for survival, it may influence herd productivity and vigor by moderating temperatures and thus reducing physiological stress levels.

Forage

Areas that do not provide cover, such as meadows and open sapling-pole stands, are classified as forage areas. These areas generally have an overstory canopy closure of <70 percent and an average tree height of ≤ 40 feet.

Natural and artificial open areas in heavily forested areas often produce more forage than forest stands on similar sites and may be used extensively by elk if security cover is nearby. Logged sites typically produce substantially more forage than adjacent unlogged areas. Depending on the site productivity, this increase in forage production may last for 100 years in the northern Rocky Mountains (Lyon 1966), but 30 to 50 years is probably more typical in northern Idaho (Pengelly 1972). But the relationship between logging and elk populations is much more complex than a simple forage production model. Hanley and others (1987) have shown that the productivity and quality of vegetation in openings may vary considerably. Plants in certain logged areas may not be as palatable or nutritious as those occurring in forested areas. Hence, the actual nutritional value of logged areas may be something less than biomass measurements indicate. Such a relationship may have important implications for wildlife in that low quality forage areas may translate into a relatively unproductive elk population with low calf:cow ratios, low growth rates, and low overwinter survival, whereas high quality habitats may result in more productive, vigorous herds--with obvious management implications. Some recent habitat effectiveness models consider this (for example, Wisdom and others 1986), and I suspect future models will follow.

The juxtaposition, size, and arrangement of cover and forage are also important in evaluating elk habitat. The location of openings in relation to cover and roads is critical in determining elk use of an area. Lyon and Jensen (1980) found that elk use of openings was depressed when cover was inadequate or open roads were nearby. Therefore, distance to cover is often

an important facet of elk habitat evaluation. Recommendations for this distance vary, but elk generally will use that portion of openings within 600 feet of the forest or cover edge. Such cover should be 600 to 2,000 feet wide for maximum use (Black and others 1976; Thomas and others 1979).

Obviously there is overlap between cover types--some stands that provide cover are also important forage-producing areas. To address this, Wisdom and others (1986) defined optimal cover as cover that provides security and thermal cover and forage areas.

These guidelines are just that--guidelines. They are designed to be modified by local biologists who are familiar with the unique characteristics of their area. It is not unusual to see different interpretations and applications of the guidelines in different areas, or even on adjacent Ranger Districts. To be truly useful, biologists must consider, at least subjectively, forage quality, adjacent cover, road density, slash accumulation, site treatment, and so forth. Such factors can have a profound effect on elk use of an area. Problems notwithstanding, Habitat Potential has created a framework within which managers can evaluate elk habitat in widely understood terms allowing them to compare and discuss management approaches.

HABITAT EFFECTIVENESS

Regardless of habitat potential, declines in elk use of habitat adjacent to roads have been documented throughout the species' range (Rost and Bailey 1974, 1979; Perry and Overly 1976; Hershey and Legee 1976; Marcum 1975, 1976; Burbridge and Neff 1976; Lyon 1979a, 1979b; Hayden-Wing 1979; Morgantini and Hudson 1979). The primary negative impact of high road density results from increased disturbance which displaces elk from preferred habitats. The width of the area avoided by elk ranges from 0.25 to 1.8 miles, depending on the amount and type of traffic, quality of the road, and density of cover adjacent to the road. In general, greater traffic flow on higher quality unpaved roads produces a larger area of avoidance (Hershey and Legee 1976; Perry and Overly 1976; Rost and Bailey 1979).

The avoidance of roads can be significant where road densities are high in that it can result in an effective loss of available habitat. The habitat management guidelines predict reductions in elk use ranging from 10 percent to 70 percent within 0.25 mile of an open road. Thomas and others (1979) reported habitat effectiveness for elk in Oregon can approach zero when road densities reach 6 miles per section. Lyon (1979a) calculated a road density of 3 miles per section would leave almost no effective habitat for elk in western Montana. It is readily apparent that road density and the associated disturbance are important factors in determining overall elk habitat suitability.

More importantly, new road construction allows increased hunter access, and may lead to increased hunter densities and higher elk harvest rates (Coggins 1976; Legee 1976; Thiessen 1976; Basile and Lonner 1979; Morgantini and Hudson 1979). Travel restrictions may mitigate the influence of roads on elk habitat use. Travel restrictions had a significant impact on elk distribution and hunter use in an area with open vegetation types, leading to a more even distribution of hunting pressure, elk sightings, and elk harvest, though the totals remained the same (Basile and Lonner 1979). Conversely, Lyon and others (1984) reported that travel restrictions did not alter elk distribution or the temporal distribution of hunters in an area with heavy cover.

ELK HABITAT MANAGEMENT GUIDELINES

Elk habitat management guidelines are based on a generalized model that incorporates a cover:forage function and a road density function. They are widely accepted and have been used throughout the western United States for several years. But the model has not been applied consistently because of "mechanical difficulties" and individual biologists' interpretations.

Mechanical difficulties arise because several different road models are available (Lyon 1979a, 1983; Perry and Overly 1976, 1977) and there are many ways to measure and calculate the cover:forage function (for example, PI types, habitat components, habitat types). Using different combinations of a road model and cover:forage calculation, a biologist can come to significantly different conclusions resulting in different management scenarios for a given piece of elk habitat.

To address this problem, Lyon (1984) conducted field validation tests to evaluate the road models and methods of calculating cover:forage ratios, and to determine the best combination for determining elk habitat suitability as indicated by actual elk use. He determined that, within the cover types tested, 50 percent of the variation in elk habitat use could be explained by an acceptable road density model. The best of the cover:forage functions improved predictions by 10 percent on only 50 percent of the validation sites.

This does not mean that cover:forage ratios are useless in terms of elk habitat management--they serve as a reasonable guideline and play a significant role in elk habitat management. It does mean, however, that we need to rethink some of our approaches to elk habitat research and management. We should be willing to take another look at elk habitat, and possibly bring in some fresh, innovative approaches before habitat potential can make a significant contribution to the models used to develop elk habitat management guidelines.

SOME POSSIBILITIES

Habitat Quality

One could look at animal condition or herd productivity as indirect measures of habitat quality. It seems that none of the currently used measures, such as blood and urine characteristics, can stand alone so it behooves us to use several simultaneously, allowing the independent measures to support each other. One could also evaluate habitat quality directly by measuring biomass and energy produced and truly available to elk in different habitats.

Coupled with knowledge of elk energy requirements (Robbins and others 1979; Parker and others 1979; Wickstrom and others 1984), this would permit a reasonable estimate of the potential carrying capacity of an area. Such information would provide a basis for the elk population targets that are so important in Forest Plans and similar documents.

Elk Mortality Rates

Determining factors that affect elk mortality rates would make a significant contribution to our understanding of elk habitat use. This includes studying road type and density, cover types, and hunter characteristics as they influence mortality rates. Elk can acclimate to roads and traffic if they are not harassed or killed (for example, Yellowstone National Park). But most elk populations are hunted, therefore acclimating to roads is generally not advantageous. Intuitively, it is apparent that different hunter groups use different types of roads in different ways, with different success rates, and different affects on elk populations. Describing such relationships would be an important aspect in determining the factors that influence mortality rate. Therefore, to determine elk mortality rates in a meaningful way, we must have good data on hunter density, distribution, attitude, and techniques given different road densities, road types, and cover types.

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EVALUATION OF GRIZZLY BEAR HABITAT
USING HABITAT TYPE AND COVER TYPE CLASSIFICATIONS

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ABSTRACT: We review the rationale for selecting habitat type and cover type as a framework for grizzly bear habitat analysis. Examples and interpretation of habitat type evaluations are presented.

INTRODUCTION

The Interagency Grizzly Bear Study Team (IGBST) was initiated in 1973 as a cooperative effort of the National Park Service, Forest Service, and since 1974 the States of Idaho, Montana, and Wyoming. The study team was charged with conducting research that would provide information for management of grizzly bears (*Ursus arctos horribilis*) inhabiting the Yellowstone area.

Habitat research has been a key part of the IGBST effort. Intensive data collection concerning grizzly bear habitat use was initiated in 1977 and continued through 1987. These data were collected principally in conjunction with radio-telemetry locations of instrumented bears and were derived from scats and detailed site description. Many data have been analyzed, and are employed in management of the Yellowstone grizzly bear; e.g., as input to the Yellowstone Cumulative Effects Analysis (Weaver and others 1986).

We stratified habitat data collection and analysis by habitat type (e.g., Steele and others 1983; Mueggler and Stewart 1980) and forest cover type (Despain 1986). In this paper we have reviewed our rationale for employing habitat types and cover types as we did, and give examples of analysis results and how the classifications served as an effective basis for grizzly bear habitat evaluation in our study area.

Paper presented at the symposium, "Land Classifications Based on Vegetation: Applications for Resource Management," Moscow, ID, November 17-19, 1987.

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STUDY AREA

Our study area was approximately 2 million hectares in size, and consisted of high elevation central plateaus surrounded by extensive high relief mountain ranges. Elevations ranged from 1575 m to 3500 m, but were largely between 2100 m and 2750 m. The central plateaus were characterized by sterile and seasonally dry soils. The more fertile encircling mountains received varying amounts of precipitation depending on elevation, latitude, and longitude (Baker 1945). The climate was further characterized by long, cold winters and short, cool summers; average annual temperatures at study area weather stations ranged from 0 °C to 4.5 °C (NOAA climatological data).

Most of our study area lay in the subalpine zone. Smaller portions were in montane and alpine zones at lower and higher elevations, respectively (cf. Daubenmire 1978). Within the subalpine zone, lodgepole pine (*Pinus contorta*) stands encompassing sapling to near-climax conditions were predominant. Whitebark pine was especially common above 2545 m elevation. The ground layer was low and lacked diversity in most forest stands. Nonforest areas were typically dominated by graminoids and lower growing forbs; sagebrush (*Artemisia* spp.) species were also common.

Numerous mammal species occupied our study area. Large herds of bison (*Bison bison*) and elk (*Cervus elaphus*) occurred principally inside Yellowstone Park; smaller numbers of mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), moose (*Alces alces*), and pronghorn (*Antilocapra americana*) were also present. Small mammals were abundant and widespread.

CHOOSING A CLASSIFICATION SYSTEM

Several habitat classification systems were available for our use in data collection and analysis. Among these the most plausible choices were:

1. Develop a habitat classification specific to grizzly bears in the Yellowstone area.

2. Employ the existing habitat component classification developed for grizzly bears in northwestern Montana (cf. Zager and others 1980; Mace and Bissell 1986).
3. Employ existing habitat type and cover type classifications developed by plant ecologists for the Northern Rocky Mountains and Yellowstone area (cf. Mueggler and Stewart 1980; Steele and others 1983; Despain 1986).

The first two options were characterized by specialized classifications sensitive to parameters of grizzly bear habitat use. These types of habitat classification allowed more definitive segregation of high and low productivity or value site types, and were best suited to areas where habitat productivity was highly concentrated in distinct sites; for example, the base of particular types of avalanche chutes or early mid-successional moist-site shrub fields.

The first two options had several disadvantages. A land classification system specific to grizzly bears would have encumbered implementation of research information by management agencies. Our study as well as management agencies would not have been able to use existing ecological classification systems and associated maps and expertise for habitat evaluation and analysis. Our data also suggested a gradient of productivity not characterized by concentration in a few well-defined site types. In addition, Option 1 would have exacted the expense of sampling and analysis as well as the inconvenience of a *posteriori* development. Option 2 was disadvantaged by limited extrapolability; foods differed in distribution, availability, and importance to respective bear populations in northwest Montana and the Yellowstone area.

Option 3 was favored by several key factors. Ecologically versatile, field-tested habitat type classifications already existed. Technicians and consultants were available who were familiar with the systems and their use. Most importantly, managers were familiar with the Daubenmire habitat classification approach (cf. Daubenmire and Daubenmire 1968) and were involved in mapping large portions of the Yellowstone area accordingly; mapping has continued and should be completed for all occupied grizzly bear habitat within the Yellowstone area by 1988. Existence of these maps and acceptance of the classification system by managers favored our analysis and use of analysis results for evaluation of grizzly bear habitat and impacts of human activities.

Habitat types have potential shortcomings as a framework for analyzing and predicting wildlife habitat use. Because these types are general in nature, key parameters of habitat value may not be explicitly recognized; for example, density, species, and diameter-class of arboreal species or age and species composition of a shrub field.

Another aspect of this criticism is that successional stage is not implicit in a habitat type designation; value of a given site to bears may be as much or more a function of successional stage as of habitat type. Further, much wildlife habitat use is keyed to microsites; a habitat type classification does not provide sufficient resolution to delineate these microsites.

We examined these potential shortcomings and concluded that all could be answered or were irrelevant given our study area and analysis objectives. Succession in the Yellowstone area appeared to be less complex than in more fertile and well-watered ecosystems such as in north Idaho or northwest Montana. The typically drier or infertile sites of Yellowstone engendered fewer potential successional pathways; typically the species occupying and dominating early successional communities were the same as those abundant in near-climax stands (Romme 1982; Despain 1983; Despain, pers. comm.). Thus, we deemed the forest cover type classification developed and described by Despain (1986) an adequate accounting of succession in forest habitat types of the Yellowstone area. Our analysis also indicated that proportionate representation of successional cover types was correlated with habitat type; near-climax stands predominated on wetter or higher elevation habitat types, while early to mid-successional stands predominated on more productive lower elevation types (fig. 1). This followed from

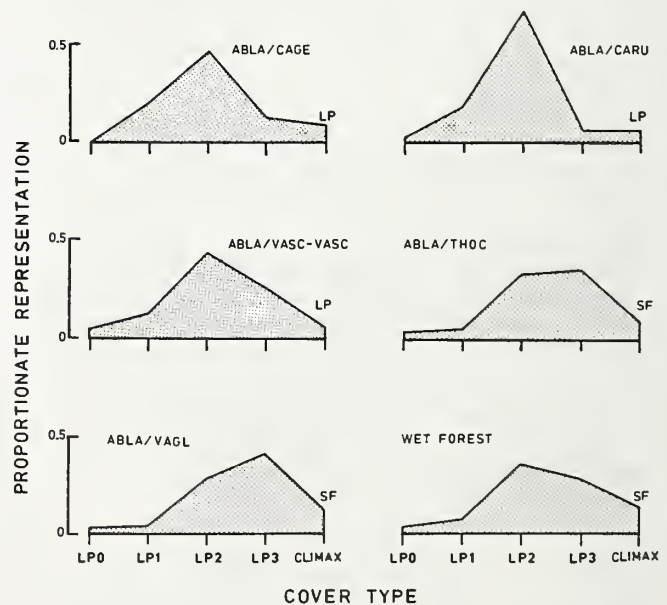


Figure 1--Proportionate cover type representation, by habitat type, for Yellowstone National Park.

the influence of elevation and site moisture on biomass and moisture content of fuels and consequently on time-specific probability of stand replacement fires within the time required for succession to near-climax conditions. This relationship between habitat type and successional stage was evident no doubt because very little of the timber in our study area was harvested or otherwise manipulated by humans. Thus, for a very large-scale analysis, habitat type also adequately accounted for successional stage.

We viewed our analysis in hierarchical terms. One of our objectives was to develop expedient and biologically meaningful methodology for evaluating grizzly bear habitat over a large area; this was significant because our study area encompassed approximately 2 million hectares. Within this expanse, we needed to differentiate productivity of areas as large of 200,000 hectares. At this scale, recognition of microsites was superfluous. While recognizing that grizzly bear use of habitat was keyed to specific parameters and microsites, we also observed that microsites were typically correlated with habitat types. We concluded that, on a large scale, habitat types would be an adequate framework for characterizing grizzly bear habitat use, while recognizing that all included activities did not occur on every hectare of a given habitat type and were more or less keyed to site variation within habitat types. At finer resolution analysis and evaluation of habitat we prioritized characterization and recognition of productive microsites.

For the remainder of this paper we will demonstrate how we used habitat type classifications and their derivatives as a framework for characterizing grizzly bear habitat use and evaluating habitat conditions in Yellowstone National Park. As part of this demonstration we analyzed habitat conditions during 1986, contrasted these conditions with those of 1979 and 1980, and interpreted habitat conditions in terms of consequences to the grizzly bear population.

EVALUATION OF HABITAT CONDITIONS

Habitat Type Evaluation

Yearly Averaged Productivity--We estimated habitat type productivity as a function of bear use, including observed feeding activity and information derived from scat analysis. Calculation of habitat productivity scores (HPS) for habitat types incorporated several factors: average feedsite density within a type, unit volume energetic value of extracted foods, and relative extracted volume per feedsite type. Feedsite density resulted from dividing number of recorded feedsites by proportionate habitat type area. This relative density estimate was weighted by mean value of feedsites recorded in the types, in turn a product of multiplying unit

volume energetic value by relative volume extracted for different feeding activities. Habitat productivity scores were thus value-volume weighted density estimates of extracted food recorded within habitat types. This approach evolved from methodology described for calculating habitat productivity scores by Mattson and others (1986).

We calculated habitat productivity scores on a by-year, by-season basis, where we had sufficient data. Seasons were defined as April-May (APR-MAY), June-July (JUN-JUL), August (AUG), and September-October (SEP-OCT). These seasons reflected marked differences in food habits and habitat use patterns of grizzly bears in the Yellowstone area. With year- and season-specific HPS's available we were able to estimate year-to-year variation in productivity of types for each season. From this estimate we also calculated a coefficient of year-to-year variation (S/\bar{X}). An estimate of feeding activity diversity (e_H , where $H = -\sum p_i \ln(p_i)$ (Shannon and Weaver 1963)) further characterized bear use of habitat types.

As an example, we estimated these variables for SEP-OCT, averaged for the years 1977, 1978, 1979, 1980, 1982, and 1986 (table 1). HPS varied 7X between low values of the Wet Meadow and Abia/Vasc-Vasc types to Abia-Pial's high value. This range of values was largely a function of whitebark pine (*Pinus albicaulis*) nut use and density of squirrel middens; grizzly bears used the high value pine nuts primarily by excavating squirrel caches of whitebark pine cones in middens (Kendall 1983). Given this range of average HPS's, fall productivity was most stable year-to-year in Wet Forest and Feid/Agca-Gevi types and least stable in Marsh/Fen, Wet Meadow, and Willow types. Year-to-year variation was not obviously related to diversity of feeding activity. Diversity was highest in the wetter forest types (Abia/Libo, Abia/Vagl, and Wet Forest) and mesic sagebrush types (Arca/Feid and Artr/Feid-Gevi). Implications of these numeric evaluations were clear:

1. Habitat types that received greatest average use and of potentially greatest importance to the bear population were identified.
2. Types with greatest year-to-year variation in productivity/use were identified; greater awareness of year-to-year variation in conditions was required if conflict between bears and humans and impacts on bear habitat were to be minimized in these types. Habitat types with higher year-to-year variation in productivity were also potentially important during some years; the Abia/Libo, Abia/Thoc, Arca/Feid, and Artr/Feid-Gevi types were known to be heavily used when whitebark pine nuts were unavailable.

Table 1--Mean diversity of feeding activity (e^H) and mean (\bar{X}), standard deviation ($S_{\bar{X}}$), coefficient of variation (C.V. = $S_{\bar{X}}/\bar{X}$), and maximum yearly value (MAX) for September-October habitat productivity scores, for the years 1977, 1978, 1979, 1980, 1982, and 1986, by habitat type or component

HABITAT TYPE (ACRONYM)	HABITAT PRODUCTIVITY SCORE				
	\bar{X}	$S_{\bar{X}}$	C.V.	MAX	e^H
Feid/Agca-Gevi	15.8	9.8	0.62	31.7	1.88
Wet Meadow	5.8	9.0	1.56	18.9	2.45
Marsh/Fen	14.6	33.7	2.45	82.5	2.00
Artr/Feid-Gevi	13.1	13.5	1.03	30.1	2.50
Arca/Feid	10.3	16.4	1.60	37.3	2.55
Willow	18.1	25.7	1.42	63.7	2.23
Psme(Abla)/Syal	7.3	10.6	1.45	27.2	2.23
Pico/Putr	7.4	5.1	0.70	14.0	1.38
Abla/Cage	7.7	7.4	0.97	19.9	1.70
Abla/Libo	14.0	16.2	1.16	35.2	2.43
Abla/Vagl	7.5	8.8	1.17	20.5	2.93
Wet Forest	10.9	5.4	0.50	17.8	2.60
Abla/Thoc	14.0	15.7	1.12	35.0	2.05
Abla/Vasc-Vasc	5.8	6.6	1.12	18.4	2.52
Abla/Vasc-Pial	27.2	26.9	0.99	66.3	1.66
Pial-Abla	42.6	34.3	0.80	73.5	1.62

- Habitat types with several versus few kinds of feeding activity were identified; bear use of types with essentially one kind of feeding activity and one associated diet item would have been more vulnerable to detrimental management actions or climatic phenomena.

moderate value foods. Seasonal patterns in mesic nonforest types were more complex; generally a decline in diversity accompanied peak use of yampa (*Perideridia gairdneri*) roots (during AUG in Artr/Feid-Gevi and during SEP-OCT in Feid-Agca-Gevi).

Seasonal Variation--Habitat productivity scores and feeding activity diversity of types varied substantially among seasons. As an example, seasonal scores and diversity were calculated for habitat types during 1986 (fig. 2). Examination of these patterns provided insight into how grizzly bears used their habitat and also provided a basis for management response to seasonal differences in bear use of habitat types. Although dissimilar in habitat characteristics, the Shaded Wetland and Abla-Pial types evidenced nearly identical trends in productivity and diversity; productivity was low in spring and fall, and peaked in early summer. Diversity of feeding activity peaked after peak in productivity. Both of these types were utilized by bears to obtain high value foods (spawning cutthroat trout (*Salmo clarkii*) in Shaded Wetland and whitebark pine nuts in Abla-Pial). Diversity of feeding activity tended to be lower while high-value foods were most available and increased as bears turned to secondary foods. Similar phenomena were evident in the Abla/Thoc habitat type. High diversity of feeding activity was associated with moderate to high productivity after late spring in wet habitat types (Wet Meadow and Wet Forest). Higher productivity in these types derived from high-density use of a diversity of low to

Successional Variation--Habitat types were characterized by substantial within-type variation in productivity. This variation was largely attributable to environmental clines within the types rather than to "random variation"; e.g., average fall productivity in the Abla/Vasc-Vasc type tended to be greater at higher elevations, and closer to boundaries with the Abla/Vasc-Pial or Abla-Pial types. A large part of within-type variation in productivity was attributable to secondary successional stage; i.e., progression of post-fire timber stands from herb-dominated to near-climax conditions.

Evaluation of productivity by successional stage had major management implications. The effects of different fire management plans and, less certainly, different timber management practices on grizzly bear habitat productivity were able to be evaluated. As an example, we calculated productivity by successional stage for SEP-OCT. We used a classification of successional stages described by Despain (1986); briefly, within the lodgepole pine (*Pinus contorta*) succession, LPO corresponded to the herb-to-sapling stage, LP1 to the pole stage, LP2 to the mature stage, and LP3 to the over-mature or decadent stage, where substantial basal area of subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea*

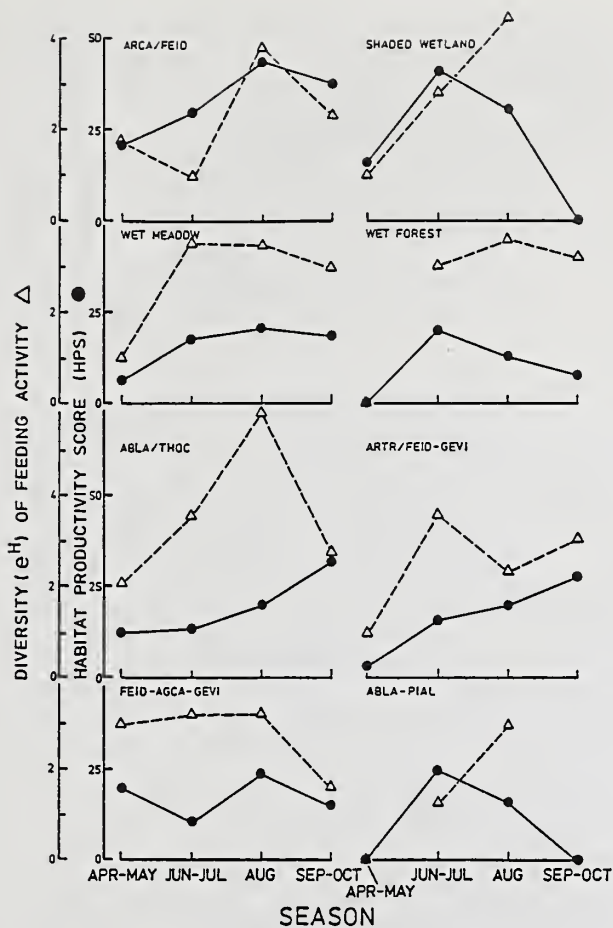


Figure 2--Seasonal habitat productivity scores (HPS) and diversity of feeding activity (e^H) for selected major habitat types in the Yellowstone area, for 1986.

engelmannii) was present. SF corresponded to near-climax spruce-fir and LP to climax lodgepole, where pole-to-mature lodgepole pine was replacing over-mature lodgepole pine in the stand.

Major trends in fall productivity scores of five major forest habitat types were evident (fig. 3). In all types productivity was lowest in the early successional LP0 and LP1 stages, and high in the near-climax SF and LP stages. Higher productivity characterized late successional LP3 stands in the Abla/Vasc-Vasc and Abla/Vasc-Pial types and mid-successional stands in the Abla/Thoc and Abla/Vasc-Pial types. Reversion of late-successional to early successional stages obviously decreased fall productivity of grizzly bear habitat in major forest habitat types of the Yellowstone area. This resulted from autecology and distribution of major diet items in the Yellowstone area; whitebark pine typically did not produce substantial cone crops until mature, and was long persistent even under near-climax conditions. Many other vegetal foods (e.g., *Osmorhiza chilensis* and *Vaccinium globulare*) were also apparently favored by semi-shaded

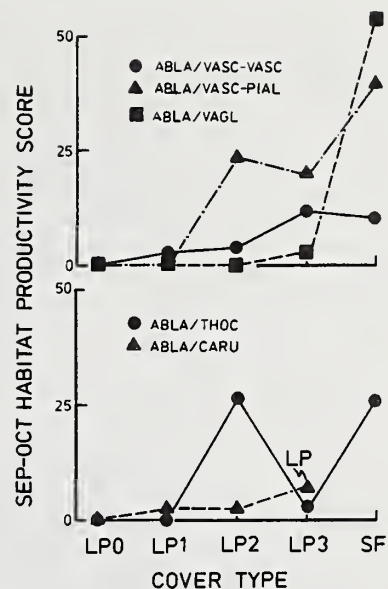


Figure 3--September-October (SEP-OCT) cover type habitat productivity scores (HPS), by selected major habitat types.

conditions typical of most mature forest stands in the Yellowstone area. Because the grazing resource was abundant, widely distributed, and apparently nonlimiting, any increase of grazing opportunity in burns or clearcuts did not offset losses of more critical resources.

Area Evaluation

Clinal Variation--Because habitat types are ecological classification units they were easily referenced to major environmental clines, in particular site moisture and elevation (as an approximation of ambient temperature). We plotted habitat types by these gradients to provide a base map against which to plot different variables (HPS, feeding activity diversity, and year-to-year variation in HPS). Mean elevation was obtained from Steele and others (1983). Site moisture was indexed by use of plant species scores. Codistribution of species among habitat types was first analyzed by cluster analysis (Hartigan 1983). Individual species were assigned a score based on observed habitat distribution with respect to site moisture (1 to 5, hydric to xeric); cluster analysis facilitated assignment of scores to species for which we had less confidence in our evaluation. Habitat type site moisture scores resulted from averaging scores of species present in the type with greater than 10% constancy.

Topological diagrams resulting from plot of HPS's along elevation and site moisture gradients provided additional insight into how productivity and bears were distributed in the Yellowstone area. As an example, we constructed topological diagrams of seasonal habitat productivity for 1986 as well as the SEP-OCT mean across all years (fig. 4). During APR-MAY

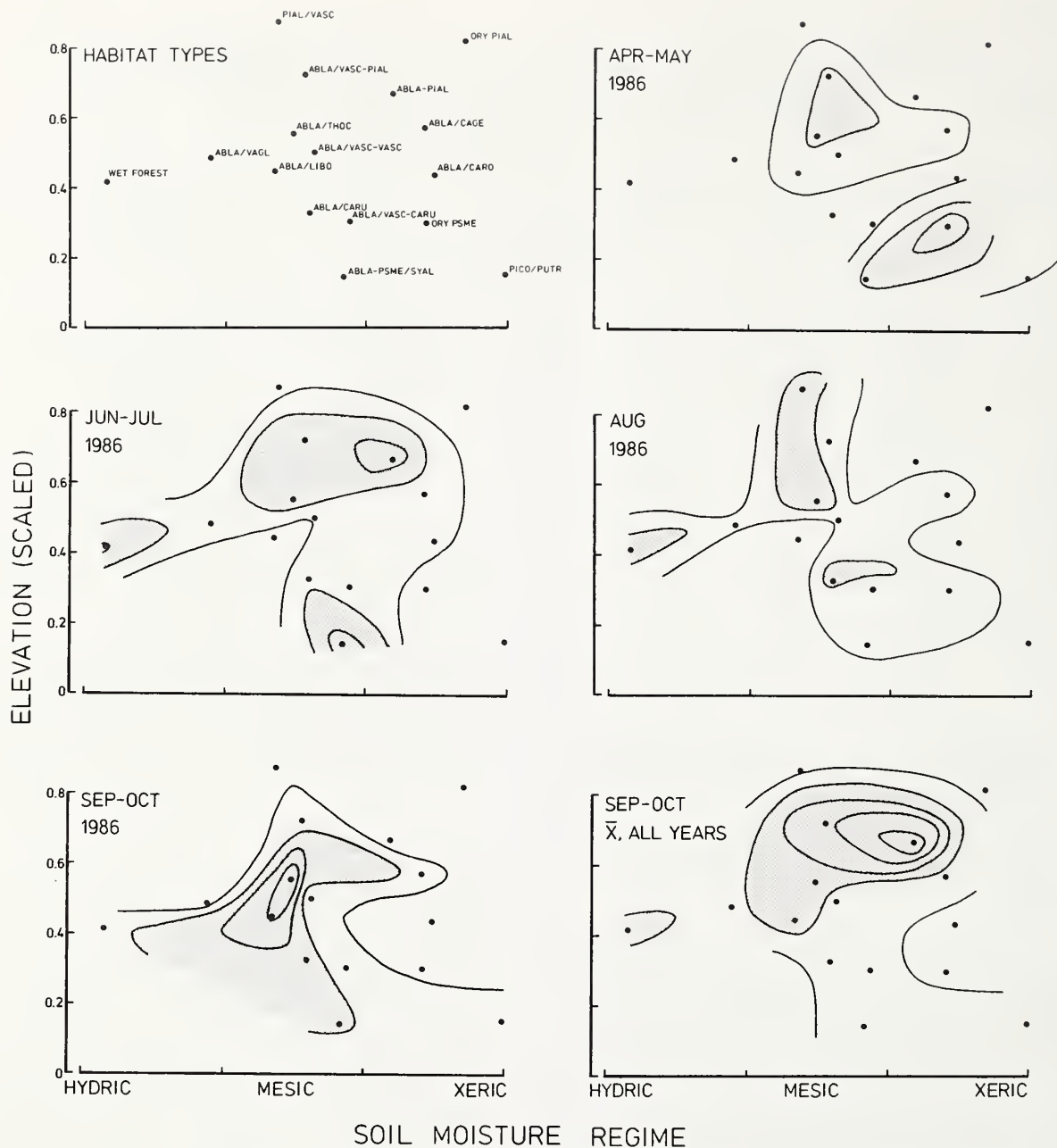


Figure 4--Topology of seasonal habitat productivity for 1986 and September-October (SEP-OCT) averaged across all years; relative to elevation and soil moisture regime.

greatest productivity occurred in association with use of ungulate carrion and squirrel caches of limber pine (*Pinus flexilis*) nuts on winter ranges at lower elevation drier sites. Secondly, productivity focused on mesic and drier sites at higher elevations in association with early season use of over-wintered squirrel caches of whitebark pine nuts and use of ungulate carrion from more isolated higher elevation winter ranges.

During JUN-JUL three major peaks in productivity were evident--at high-elevation moist-to-dry sites associated with use of the over-wintered

pine nut crop, at wet mid-elevation sites in association with use of grazed diet items and spawning trout, and at lower elevation mesic sites in association with continued use of carrion. During AUG, use of pine nuts shifted to moister sites, productivity continued high in wet sites but declined in lower elevation mesic sites.

In SEP-OCT of 1986 a major peak in productivity occurred on mesic mid- to low-elevation sites. This peak was associated with use of the grazing resource and sweet-cicely (*Osmorhiza chilensis*) roots. In contrast, average SEP-OCT

productivity across all years strongly peaked at higher elevations and on drier sites, primarily in reflection of whitebark pine nut use. During fall of 1986 virtually no pine nuts were available, and bears reverted to secondary fall foods. Use of secondary foods brought bears to lower elevations and mesic sites that also coincided with most major human facilities in the Yellowstone area. Nutritional stress exacerbated this juxtaposition and fall of 1986 was characterized by a large number of management trappings and problems involving grizzly bears.

Area Variation--We estimated habitat productivity for large areas by a simple means: habitat productivity scores were weighted by proportionate area representation of corresponding habitat types to yield a weighted average. Area scores were calculated on a seasonal and yearly basis for Yellowstone National Park. We deemed our simple approach to estimating productivity sufficient given that we were making temporal comparisons of a given area that had many time-static parameters. Comparison of different geographic areas would have entailed a more complex model, as was used in the Cumulative Effects Model for the Yellowstone Ecosystem (Weaver and others 1986).

As an example of this calculation, we derived fall (SEP-OCT) habitat productivity scores for the years 1977, 1978, 1979, 1980, 1982, and 1986 (table 2). Area scores varied by 2.5X (C.V. = 0.32) from low scores in 1977 and 1986 to high scores in 1979 and 1980. These year- and season-specific productivity scores were apparently related to population phenomena of the Yellowstone area grizzly bear. Adult female mortality and total mortality for the period 1977 to 1982 were related to fall HPS ($r = -0.85$, $P = 0.07$; $r = -0.86$, $P = 0.07$, respectively); virtually all known mortality of subadult and adult bears in the Yellowstone area was by humans and occurred in fall or late summer. By implication, during years of lower habitat productivity, more bears came in conflict with humans and were killed. As previously mentioned, this was likely a consequence of nutritional stress and juxtaposition of human facilities and secondary fall habitat.

Table 2--Fall habitat productivity score (HPS), adult female and total mortality, and number of management trappings, by year

Year	Fall HPS	Adult female mortality	Total mortality	Management trappings
1977	5.6	4	17	5
1978	9.8	2	13	0
1979	12.2	2	13	0
1980	13.8	1	10	0
1982	9.5	4	17	7
1986	6.9	2	11	31

Between 1982 and 1986, managers increased efforts to preserve adult females. This was a consequence of analyses suggesting that death of one additional adult female each year constituted the difference between a stable and declining population (Knight and Eberhardt 1984). Given that mortality appeared to be inversely related to habitat productivity, effectiveness of management actions in reducing mortality rates could not be judged without accounting for habitat conditions. Regression analysis of the relationship between adult female mortalities (y) and HPS(x) yielded:

$$\hat{y} = (2.77 - 0.119x)^2; \text{S.E.E.} = 2.6; \\ P = 0.06, r^2 = 0.73$$

Given HPS = 6.88 for SEP-OCT of 1986, predicted adult female mortality was 3.8 (4). Observed mortality (2) was substantially less than the predicted level, although within the 95% prediction interval. This suggested that management actions were effective in reducing human-caused mortality of bears during 1986.

We were also able to examine area distribution of habitat productivity by apportioning habitat type areas according to season- and year-specific habitat productivity scores. As an example, seasonal distributions were calculated for 1986 as well as SEP-OCT distributions for 1979 and 1980 (fig. 5). The proportionate area of Yellowstone Park producing virtually no food ($\text{HPS} < 1$) increased from a low in APR-MAY to a high in AUG and SEP-OCT; on the other hand proportionate representation of the most

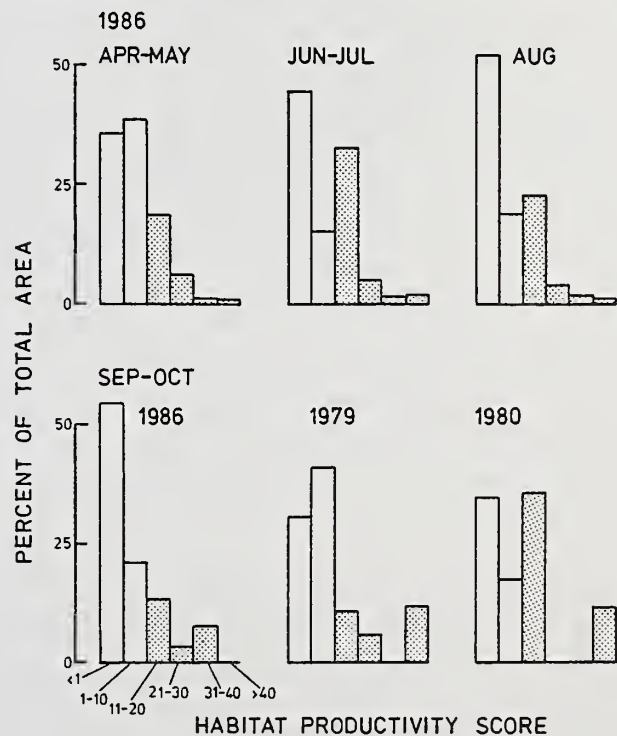


Figure 5--Seasonal habitat productivity score class, as a percent of total area in Yellowstone National Park, for 1986 and for September-October (SEP-OCT) of 1979 and 1980.

productive habitat (HPS > 30) was greatest in SEP-OCT. A comparative abundance of moderately productive habitat existed APR-MAY through AUG.

During fall of 1986 a limited area of highly productive habitat was available, compared to more productive years such as 1979 and 1980. Given that dominant animals (e.g., adult males) very likely preempted this productive habitat during relatively poor years such as 1986 (Mattson 1987), a large portion of the bear population had to make do with a comparatively restricted area of mediocre habitat in 1986; a key difference between 1986 and 1979-80 was the large proportion of habitat in moderately productive condition (>1 and <31) during 1979-80. Bears would have had much greater space to meet their energetic demands during these more productive years. Limited spatial representation of moderate to highly productive habitat further explained the large number of management trappings involving problem bears during 1986 (31) compared to absence of all such actions during years such as 1979 and 1980 (see table 2).

SUMMARY

We chose to employ habitat types in combination with successional cover types for habitat stratification and analysis. These classifications were comprehensive in their treatment of the landscape, well accepted by area managers and researchers, and developed according to general ecological principles.

We employed habitat types as a framework for describing productivity and use of habitat by bears and also as a foundation for evaluating distribution and variation of habitat productivity on much larger scales. These evaluations were, in turn, a basis for understanding bear behavior and population phenomena. We calculated mean productivity scores and their year-to-year variation as well as diversity of feeding activity for habitat types. Within-type variation in productivity was stratified by successional stage. Further refinement of habitat analysis below the level of habitat type and cover type was necessary and applicable to evaluation of foraging strategies and site-specific, human-induced impacts. Habitat types were a basis for analyzing distribution of bear habitat productivity with respect to environmental gradients and area and for calculating habitat productivity scores for Yellowstone National Park.

In short, habitat types served as a very efficient information storage and retrieval system and a legitimate basis for habitat analysis. This assessment is certainly qualified by idiosyncracies of the study area environment and the animal we studied: the relative heterogeneity of much of the habitats and comparatively simple successional pathways facilitated use of habitat types as we did. Also, a wide ranging animal such as the grizzly bear made a coarser stratification of the environment such as is provided by habitat types

acceptable for large-scale analysis. A key part of using any ecological classification system for analysis of wildlife habitat, as we see it, is description of temporal and spatial variation within units. The ecological classification can be, in turn, a key tool in describing temporal and spatial variation of a large study area such as ours.

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APPENDIX: HABITAT TYPE ACRONYMS AND DERIVATIONS

Acronym

Feid/Agca-Gevi	Festuca idahoensis/Agropyron caninum-Geranium viscosissimum phase ¹
Wet Meadow	Phleum alpinum series ²
Marsh/Fen	Carex rostrata, Carex aquatilis, and Carex vesicaria series ²

Shaded Wetland	Calamagrostis canadensis series ²
Artr/Feid-Gevi	Artemisia tridentata/Festuca idahoensis-Geranium viscosissimum phase ¹
Arca/Feid	Artemisia cana/Festuca idahoensis habitat type ¹
Psme(Abla)/Syal	Pseudotsuga menziesii (Abies lasiocarpa)/Symphoricarpos albus habitat type ³
Pico/Putr	Pinus contorta/Purshia tridentata habitat type ³
Abla/Caro	Abies lasiocarpa/Carex rossii habitat type ³
Abla/Cage	Abies lasiocarpa/Carex geyeri habitat type ³
Abla/Caru	Abies lasiocarpa/Calamagrostis rubescens habitat type ³
Abla/Libo	Abies lasiocarpa/Linnea borealis habitat type ³
Abla/Vagl	Abies lasiocarpa/Vaccinium globulare habitat type ³
Wet Forest	Abies lasiocarpa/Calamagrostis canadensis and Picea engelmannii/Equisetum arvense habitat types ³
Abla/Thoc	Abies lasiocarpa/Thalictrum occidentale habitat type ³
Abla/Vasc-Vasc	Abies lasiocarpa/Vaccinium scoparium-V. scoparium phase ³
Abla/Vasc-Pial	Abies lasiocarpa/Vaccinium scoparium-Pinus albicaulis phase ³
Pial/Vasc	Pinus albicaulis/Vaccinium scoparium habitat type ³
Abla-Pial	Abies lasiocarpa/Arnica cordifolia, Abies lasiocarpa/Ribes montigenum, and Abies lasiocarpa/Juniperus communis habitat types ³

¹Mueggler and Stewart 1980

²Mattson 1984

³Steele and others 1983

HABITAT TYPES AS A VEGETATION MANAGEMENT TOOL

Wendel J. Hann

ABSTRACT: The habitat type system developed by Daubenmire has been implemented and tested in vegetation management. This system has proved to be as valuable in nonforest as in forest ecosystems. Some problems have occurred as the system has been developed and implemented. These problems can be solved through improvements and increased training. Major improvements can be made in the ability to predict response of vegetation and environmental effects to various management practices. The habitat type classification system provides a critical framework for development and improvement of this predictive capability.

INTRODUCTION

Habitat types (Daubenmire 1952) provide the basic framework for design of vegetation management prescriptions. This system of classification has proved to be very effective, yet some problems have developed in application. Problems with broad variability within types and misidentification of habitat types have reduced accuracy of predictions of vegetation response, productivity, and environmental effects. These problems can be reduced by refining classifications, increasing our understanding of causal variables, and training people to improve their identification abilities.

Inventory of existing and potential vegetation, along with physical parameters, is a basic foundation for evaluating and designing vegetation management practices. The ability to predict response to various alternatives is fairly limited, if all that is available is a prediction of the potential vegetation. Succession and environmental effects models, stratified by habitat type, provide the type of system that is needed to adequately evaluate a range of alternatives. Linkage of inventory data, prediction models, and spatial relationships on computer systems make it possible to rapidly and efficiently analyze a broad range of alternatives.

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The evaluation of alternatives and design of prescriptions occurs at two levels. An evaluation of vegetation response and site specific environmental effects can be made at the stand level. Larger scale evaluations of cumulative effects, mosaic diversity, and resource levels are done at the area level. Habitat types have provided a framework for communication, information storage, and stratification of response predictions. This framework is a critical part of the stand and area vegetation management process.

APPLICATION OF CLASSIFICATIONS AND DEFINITIONS

Interpretation of Definitions

In order for vegetation managers to fully utilize habitat types, they need to understand the basic process of classification development. The investigator that develops a habitat type classification is integrally involved. Consequently, the concepts and process related to the habitat type classification should be clear to the investigator. This process, and the limitations, may not be clear to managers that are attempting to interpret the classification to predict vegetation response, productivity, and value for various resource uses.

The primary objective for development of the habitat type classification is to describe the potential plant communities that occur on various environments of the landscape. This is accomplished by searching for communities that are considered, by the investigator, to be expressions of the potential for a site. These communities are those that are considered to be at the endpoint of secondary succession, have a stable species composition, and are in equilibrium with their environment (Barbour and others 1980; Daubenmire 1968; Mueller-Dombois and Ellenberg 1974).

Communities are described by sampling macroplots, within each community, and an analysis is used to group similar macroplots into an aggregate that represents a community type. The average of the sampled macroplots in the type is used to describe the vegetation and environmental attributes. Plant species that consistently occur in the type are used as indicator species to assist in identifying the community type. A "community type" includes all the communities that have similar species composition and is identified by one or more indicator species. The community type classification can be used for both the

potential community or seral communities. In the case of the habitat type classification, the potential community type is classified to assist in identifying the potential for a type of site or land.

A habitat type is "all the area (sum of discrete units) that now supports or within recent time has supported and presumably is still capable of supporting one plant association" (Daubenmire 1952; Daubenmire 1968). An association is the climax or potential community type. For application, all the land or sites that have the capability to support one potential community type make up one habitat type. Each site has an environment in which the combined effects of the soil, climate, aspect, slope, elevation, and other physical parameters produce a potential community.

The indicator species for a potential community type usually have a fairly broad ecological amplitude and, thus, occur across a wide range of sites or environmental conditions. Compensating environmental factors can produce the same plant environment on sites that have very different individual factors. For instance, the same potential community type can occur on two different sites within one geographic area; one site that is a high elevation, steep south slope, with excessively-drained, gravelly soils on limestone parent materials; the other site that is low elevation, gently rolling, with well-drained loamy soils on sandstone parent material. Changes in geographic area that create different climates also can produce very different site conditions that will support the same potential community type. Consequently, the habitat type usually contains considerable variability in combinations of environmental factors.

To reduce this variability, an additional indicator species is often used to split the habitat type into phases (Pfister and others 1977). However, even at the phase level there is often considerable environmental variability within the type. This variability can be reduced by splitting the potential community type into ecological types, using geographic area, soil characteristics, and topographic classes. An ecological type includes all the land or sites that have the capability to support one potential community type, and have relatively uniform climate, soils, and topography such that their ability to produce vegetation and respond to management is similar (Stewart and Hann 1983; USDA Forest Service 1986; Hann and Jensen 1988).

Other classification systems have been developed that are based on the same concept of identifying land that will support one type of potential community. The range site classification system was developed for areas with nonforest potential (USDA Soil Conservation Service 1976). Sites are grouped based on their productivity and type of potential community, and are typically named for their soil texture, soil depth, and/or place in the landscape. Consequently, the range site, in definition, is similar to the ecological type. However, in actual use, there is often more than one type of

potential community included within a range site, due to problems with disturbance and a lack of adequate samples on undisturbed sites. An additional problem is that there is often only one macroplot sample used to describe the modal concept of the range site. This approach does not describe the variation within the range site and can lead to errors in interpretation.

An ecological problem with the basic definition of the range site classification is its restriction to rangeland ecosystems. From a conceptual viewpoint, an ecological land classification should be appropriate in both rangeland and forest ecosystems. The term ecological site has been used by the Bureau of Land Management in a similar manner to the range site.

Identification and Variability

The field identification of habitat types, by personnel conducting inventories, is often more difficult than development of the classification. Most communities in the northern Rocky Mountains, Great Plains, and Great Basin have been disturbed and are not at the endpoint of secondary succession, do not have a stable plant species composition, and are not in equilibrium with their physical environment. These communities are seral communities. A majority of the western landscape supports plant communities that are in this condition, due either to natural or human-caused vegetation disturbance. This situation is not necessarily negative. In many cases a seral community is the desirable situation for natural diversity, ecosystem management, and productivity.

The typical habitat type classification is based on pristine sites that can be found within the geographic study area. The investigator searches the geographic area for undisturbed sites that express the potential and uses data collected from these sites to develop the classification and identify indicator species. The average species floristics and composition for each type are given to represent the type. Most classifications include a cursory evaluation of site characteristics and the physical descriptions typically describe the aspects, elevation zones, slopes, climatic influences, and broad soil characteristics of the type. Very few classifications attempt to classify the site variability into ecological types within the habitat type or to identify the seral patterns in relation to type of disturbance. This typical process contains some inherent problems that often make it difficult for field personnel to accurately identify the habitat type, or can lead to misinterpretations about the type. These problems are summarized in the following four points:

1. Biased sampling. Most investigators only sample those sites that are considered pristine or relatively similar to the potential for the site. Consequently, there is a fairly high probability that there will be types that are not classified because sample selection is biased towards communities that are

undisturbed. Certain types exist where there are no examples of the vegetation potential for the site, since all of the communities within the type are disturbed, or have not had adequate time to stabilize. Sampling is also often biased towards the investigators' preconceived ideas for the modal concept of the type. Communities that do not fit this modal concept, ecotones, and unique situations are usually not sampled. The result of a classification with missing types, when used for inventory and interpretation, is a misidentification or a land stratification that does not fit in the framework. Misidentification can cause errors in interpretation, while the inability to name a given piece of land creates a gap in our ability to predict potential and response to management.

2. Variability. Presence of one or more indicator species is typically used to identify a type. The amplitudes of the communities these indicator species occur in are usually very broad in variability of species floristics, composition, and environment. Most habitat type classifications do not have adequate samples to describe this variability. Since species floristics and composition do not have a normal distribution across a type, any one community has a fairly high probability of being very different from the average. Most classifications emphasize that, in addition to using the key, the user should always compare the community to the species list and average composition for the type to assure that it is similar. In a stand that is disturbed and has only low or moderate similarity to the potential, where an adjacent undisturbed stand in the same environment is not available, this comparison may not be meaningful. Consequently, accurate identification of a type where the vegetation has only low or moderate similarity to the potential may be very difficult if the investigator has not developed a reliable environmental model that predicts the potential based on climate, soils, and topography. Although a community may fit the general description for the type, the indicator species may not be present. Field personnel often misidentify these situations by placing too much emphasis on presence or absence of indicator species.

3. Accuracy of interpretations. Interpretations from the classification relative to vegetation composition, production, response to disturbance, and environmental characteristics are based on the data collected to develop the classification. Very few classifiers collect additional data to test the variability of types, or to add to the ability to predict response and environmental parameters. Consequently, predictions that use an average, or even a range, may have very low reliability due to the large amount of variability and minimal sampling.

4. Correlation with other classification systems. There is often confusion in discussion of correlation of land classification systems versus correlation of plant species or environmental factors. Various investigators have argued for or against the concept that there is a correlation between soils and habitat types. The problem with this argument is a lack

of separation of environmental factors from soil classification. Those investigators that have tried to use soil classification at the series, family, or more general levels to make direct correlations with habitat types were usually unsuccessful. The attributes used for soil classification at those levels do not provide explanation at the level that would correlate with a potential vegetation type. However, the correlation is usually very high for those investigators that split soil series into phases using aspect, slope, elevation, landform, geographic climatic area, soil surface texture, and other environmental variables that are highly correlated with plant species occurrence and distribution.

The problems that have developed from our typical process of classification of potential communities should and can be corrected. Since the habitat type classification identifies land that produces types of potential communities, it is a land classification. The process of classification should involve sampling of the physical environment at an equal level to sampling of the potential communities. If different types of physical environments are found, for which no communities can be found that are similar to the potential, then they should be sampled, indicator species identified, and the community type that is furthest developed towards potential used to identify the type. This process will help avoid missing types due to a lack of undisturbed communities.

Habitat types should be further split into ecological types based on site factors that influence vegetation production and response to management. Sampling should be adequate to describe each type of site within the geographic study area. While classifying site potential, it may also be appropriate to classify seral stages and community types for each ecological type. An understanding of the communities that result from different types of disturbance will help identify the potential for the type of site. This process will reduce variability and improve accuracy of interpretations.

There are some common errors in understanding of the habitat type system that affect accuracy of identification. These types of errors can be corrected by proper training of field personnel. These errors are summarized in the following three points:

1. A common problem that causes errors in identification is the idea that personnel only need to be trained to identify the indicator species in order to identify the type. If they cannot identify the other common species in the type, they cannot confirm identification by comparing the species floristics and composition of the community to be identified with the average for the type.

2. Personnel using the classification key without proper training often select the dominant species to use as the indicators. This often causes an error in identification since species are not evaluated that have decreased due to disturbance, are of younger age and/or smaller size, or are not yet present in the

community because it is in an early successional stage. A common error in forested communities is to pick the tree indicator species that is in the overstory rather than the more tolerant, later successional tree species coming up in the understory. These understory species are usually indicators of the true potential. A common error in nonforest communities is to pick the dominant shrub and/or grass as the indicator species and not look for species that have been depleted due to grazing. These species may often be found under a shrub overstory where they are protected from grazing or as remnant individuals in the community. A properly constructed key that organizes species and types from moist to dry, tolerant to intolerant, desirable to undesirable, and gives clues on what to expect in disturbed conditions, will help avoid this problem.

3. Personnel that are not trained in identification of plants to the level required by the classification will misidentify indicator plants and other common plants and, thus, misidentify the type. The habitat type guide, manual or instructions should specify the plant species and level of identification ability needed to properly use the classification.

Inventory--Mapping, Sampling, and Summary

In order to evaluate vegetation management alternatives and predict response, an inventory of both the site potential and existing vegetation is needed. Common inventory systems have involved mapping of habitat types, soil types, and cover types. As seral community type classifications are developed by habitat type, the combination of community type/habitat type can be mapped. Map delineations of stands can also be sampled by replicating plots where specific vegetation or site attributes are measured. The average and variation of these measurements can then be used to describe the stand. A complete inventory of delineated stands will usually involve mapping of soil type, habitat type, and cover type, along with sampling of specific attributes that need to be statistically described, such as size and density of trees or forage production.

A problem consistently encountered when mapping vegetation and soils is the complexity of variation versus the smallest delineation allowed by the map scale. When delineating vegetation stands on a map, the true complexity of communities and their environments can usually not be mapped because the map scale is too small to allow delineation. Consequently, within one vegetation stand delineation, there may be more than one habitat type, soil type, and/or existing community type. This is not a problem if the stand can be sampled and data analyzed in a manner that describes this variation.

An important part of the inventory process is the provision for objectives and standards. Inventories should be designed to meet specific information and decision-making needs. The inventory system should provide a consistent

approach and format and have standardized codes and measures of accuracy. In the Northern Region of the Forest Service there are two systems that provide consistency in data format and accuracy. These include the Stand Exam Procedures chapter of the Timber Management Data Handbook (USDA Forest Service, 1985) and the Ecodata chapter of the Ecosystem Classification Handbook (Hann and Jensen 1988). The Stand Exam system provides standards and format for plot data of tree measurements, and the Ecodata system provides standards and format for plot data of vegetation and site measurements. There are standard computer data entry, analysis, and prediction programs as complements to both these systems.

The advent of computers, with large storage and analysis capability, that have "user-friendly software," has made the analysis and display of large amounts of data a relatively easy task. This capability allows managers to be able to evaluate many different vegetation and site attributes for many stands and many alternatives. The implementation of computer based geographic information systems (GIS) will automate the display of inventory data and predictions with the spatial map relationships.

An important consideration for the design of an inventory system is the collection of data in a manner that facilitates description of the existing conditions and provides data for developing classifications, predictions, and records of history of treatment. A system that provides information for both types of uses increases efficiency and significantly reduces the cost of improving classifications and management implications. An example is the Northern Region's Ecodata plot system (Hann and Jensen 1988). The same plot data can be used to describe existing vegetation composition, develop a prediction for vegetation response to a type of treatment, classify a community type, determine similarity to the site potential, act as the starting point for a succession model prediction, and be used for comparison of rate of change when remeasured at a later date.

Another important aspect of inventory is the use of extrapolation. Due to the need for information on all delineated stands within an area and the lack of resources to accomplish a complete ground inventory, general data for many stands are often extrapolated. A common extrapolation technique involves estimates by personnel experienced in the area associated with evaluation of aerial photographs, map data, and ground data from stands that have been visited. A second technique involves sampling selected stands of each photo interpretation cover type/landscape stratification and applying the average of various resource and environmental attributes to all stands in the class. A third technique is to select stands to sample in each cover type/landscape stratification, and use these data to develop a multivariate regression prediction of resource and environmental characteristics.

VEGETATION MANAGEMENT PREDICTIONS

Predictions Based on the Classification of Potential Communities

Although the habitat type or ecological type classifications provide an important tool for land stratification and mapping, their application for predicting response to management is limited. A basic classification of potential vegetation provides information on: (1) the composition and productivity of the potential community type; (2) the values of the potential community type for various resource uses; (3) site characteristics of the type; and (4) hydrologic and climatic averages for the type. Very little can be gleaned from many of these classifications on how the vegetation will respond to different types of disturbance, management treatments, and rate of change over time or how the soil and hydrologic characteristics will vary with different management practices.

The most important use of the basic site potential classification is as a framework for communication, storage of information, and stratification to measure response. The classification provides a relatively uniform situation that people can visualize and talk about. It also provides a class where productivity and response is narrow enough in variability that causal factors can be identified. When the class is found to be too broad for evaluating productivity or response, it can be further stratified using environmental characteristics.

Predictions Based on Seral Classification and Modeling

In order to use a habitat type classification as a tool for prescribing vegetation management practices, predictions need to be made for vegetation response. The succession classification and modeling systems developed by Huschle and Hironaka (1980), Steele (1984), Arno and others (1985), and Keane (1987) are the type of prediction systems needed to adequately evaluate vegetation response alternatives. These systems describe vegetation composition, productivity, and rate of change in response to various natural and human-imposed treatments. In forested communities, these systems in combination with a forest growth and yield model (Stage 1973; Wyckoff and others 1982) provide a predictive process that managers can use to evaluate treatment response prior to implementation. For nonforest communities, productivity measurements must usually be stratified by seral community type and rates of change are much more difficult to predict.

In addition to being able to predict vegetation response to various treatments, managers need to assess effects of treatment and vegetation change on soil, water, air, and animals. Volumes of literature are available that summarize or give predictions for various conditions. The large amount of literature on treatment effects, and the often conflicting results, make it difficult for managers to

develop reliable predictions. A systematic, efficient process is needed for predicting effects. A computer model that accesses the basic inventory data, interacts with the user to consider treatment options and conditions, and predicts response based on tested relationships would be a desirable solution to this need. The Intermountain Forest Service's Research Station has been very active in development of these types of models for predicting fire effects and behavior, impact of various treatments on soils, and hydrologic response to different treatments. The Northern Region of the Forest Service has been implementing these models through various computer applications for field use by managers.

VEGETATION MANAGEMENT

Stand Level Evaluations

At the stand level of evaluation and prescription, variation in vegetation and site characteristics is relatively low. However, even at the stand level, there are often contrasting vegetation communities and soils, due to a complexity of variation that cannot be mapped. In these situations very different responses can come from the same treatment, within the same stand.

For analyzing response of vegetation, site characteristics, and resource values, there is a basic set of information that is needed:

1. A basic inventory of the composition and values of the existing vegetation and a prediction of the potential vegetation.
2. Information on the soil and hydrologic characteristics, their limitations, and their effects on productivity.
3. Identification of alternatives that are acceptable from both the biological and economical standpoints.
4. A prediction of the response of the vegetation over time and the effects on resource values of each alternative.
5. The value of different resource trade-offs, products, and effects related to each treatment.

From this basic set of information, managers can assess treatment alternatives for a stand, across a reasonable range of alternatives. This is a process that not only meets multiple-use requirements for public land management, but is a sound biological and economical method for evaluation of management of land, regardless of ownership.

Area-Level Evaluations

An evaluation of alternatives that has only considered the response and effects at the stand level is usually not adequate from an ecological and multi-resource perspective. Although vegetation and site characteristics may be somewhat uniform and response can be predicted at the stand level, this is not the case for

larger scale effects on water, animals, soil, air, diversity, and resource outputs. An area level of analysis that evaluates resource trade-offs, products, and effects across all stands is needed to make these types of assessments. "Cumulative effects analysis" is a term used for evaluating effects on a resource of many impacts, over time, within a biologically defined geographic area.

Area evaluations are designed to analyze alternative management practices for stands that are to be actively managed and evaluate vegetation dynamics for stands that will not be treated. When considering an area that contains several hundred stands, it is readily apparent that this can be a very complex and confusing analysis of alternatives, relative to predicted outputs and effects. The use of computers is almost a necessity to manage the data and evaluate various combinations of stand treatments.

HABITAT TYPES--THE KEY TO ORGANIZATION

Without a classification that defines potential, no two managers can communicate on the same level concerning site potential and stratification of vegetation response. Managers, without a classification of potential, usually build a framework based on existing vegetation. We have many examples that demonstrate the problems resulting from basing predictions of productivity and response on a framework that keeps changing and is not stratified by the physical environment.

The habitat type classification has provided a framework for communication, information storage, and ecosystem stratification. Dr. Rexford Daubenmire and those authors that have followed him deserve full credit for providing a system that continually leads to improved understanding of vegetation dynamics.

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RANGE SITES/ECOLOGICAL SITES--

A PERSPECTIVE IN CLASSIFICATION AND USE

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Abstract: The site climax concept, differentiations between sites, and present vegetation are discussed as they relate to range site classification and as they relate to ecological site, habitat type and community type classifications now in use. Range site and ecological site classifications provide one level of classification that are not necessarily mutually exclusive nor incompatible with habitat types and community types. Range sites/ecological sites, habitat types, and community types represent different levels of classification with different interpretational values that conceptually could be integrated into a universal classification system for vegetation communities. More important than the individual classification or their potential compatibility, however, is the need for a unifying force to establish a universal classification or taxonomy. The National Cooperative Soil Survey provides a precedent that may be helpful.

INTRODUCTION

The susceptibility of vegetation to change in short periods of time as compared to soils has presented a dilemma for vegetation classification depending on the level and kind of management interpretations desired from classification. Two general types of vegetation classification are in use, one based on climax or natural potential vegetation and the other on present vegetation. One addresses the capability of a site to produce vegetation in a natural situation while the other addresses current site production. Neither, alone, may adequately address the needs of management to identify objectives and possible solutions to problems.

Two of the most prominent classifications used in the United States are range sites (Dyksterhuis 1949; Renner and Allred 1962; Shiflet 1973) and habitat types (Daubenmire 1970; Hironaka and

others 1983; Mueggler and Stewart 1980). Both are based on the climax plant community concept. Community type classifications (Mueller-Dombois and Ellenberg 1974) are often used for present vegetation. Range condition, in context with range sites, is also a classification of present vegetation. The fact that no universally recognized classification or taxonomy has evolved for organizing, evaluating and communicating information about vegetation communities has seriously impaired our ability to extrapolate data for resource management and for applied research activities. The term ecological site was proposed by the Range Inventory Standardization Committee (RISC) (1983) and essentially used range site concepts to include natural ecosystems other than rangelands. The Bureau of Land Management (BLM) (USDI 1984) describes the term ecological site as synonymous with range site on rangelands and stated that the concept also applies to grazeable woodlands and forest sites, but there was no consensus among other classifiers.

Even if there is eventually agreement among classifiers on terminology and general concepts such as those proposed by RISC, there still needs to be a continuing process for expanding the classification as new information is obtained and for reconciling differences among classifiers. We hope that the following discussion on some aspects of range sites and their relationship to other classifications will reemphasize the fact that the ecological concepts involved are not that irreconcilably different, or at the least, not mutually exclusive. We submit that a precedent exists in Soil Taxonomy that can serve as a model to establish a standard vegetation community classification and taxonomy that meets management needs.

THE CLIMAX CONCEPT

The concept of climax gives the range site (and habitat type) concept an inherent utility but it is also one of the greatest sources of criticism. The use of the climax concept allows identification of repeatable landscape units and their associated soils and related present vegetation communities with capability to produce similar kinds, amounts, and proportions of vegetation at the presumed end-point of succession. It follows that similar landscapes should respond comparably to like management, thus providing a tool to reasonably predict and extrapolate management responses, the effects of natural phenomenon

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(fire, drought, etc), research information, and monitoring results. By quantifying and describing the associated soil, landscape and climate features, the site and, therefore, the management potential can be identified with reasonable accuracy even in the absence of vegetation (Shiflet 1973).

But how do we identify climax vegetation in the first place? The National Range Handbook (NRH) (USDA 1976) provides these methods:

(a) "Evaluation of relict vegetation and associated soils . . ."

(b) "Interpolation and extrapolation of plant, soil, and climatic data from existing relict areas along a continuum . . ."

(c) "Evaluation and comparison of areas currently grazed . . . with similar areas that are not grazed . . ."

(d) "Evaluation and interpretation of research data . . ."

(e) Review of early historical accounts and botanical literature of the area.

RISC gives us the same methods verbatim to identify the "Potential Natural Community" (PNC) except for item (c) wherein logging and other disturbances are considered in addition to grazing. The term PNC was apparently intended to encompass the climax concept, but makes allowance for the loss or gain of species. However, neither method includes any specific criteria for establishing exactly what constitutes climax. Meeker and Merkel (1984) reviewed five different climax theories. They recommended the site climax theory as used in the range/ecological site concepts, but did not identify specific criteria. Some have asked if long term stability represents climax. Walker and others (1981) present a convincing argument that at least two stable points exist for many sites. Passey and others (1982) stated "Remnants of climax vegetation are scarce in most western rangeland areas. Thus, approximation of the probable plant-community potential for many sites has necessarily been empirical."

So just how do we determine climax? Dr. Harold Heady (1984) remarked that it is impossible to prove or disprove climax except by one's own definition and that the purpose of range sites is to provide an inventory for land management and not to prove succession and climax. It is also our opinion that climax is most often determined by one's own definition. It is an opinion based on the state of knowledge and available research. The agencies have sometimes modified the opinion process through a hierarchy of responsible individuals and developed policy for site description format and a correlation process. This process provides a desirable process for incorporating additional information and provides more consistency in the site descriptions. The community portrayed is none the less an opinion, either from a consensus or occasionally based on the perception of a dominant personality within an agency. While this has been the major source of

controversy, it is one which ecologists can and should resolve. Unfortunately, there is no formal process in place for reconciling differences between agencies, university affiliates and other classifiers. Fortunately, the utility of the site concept is not necessarily dependent on the absolute knowledge of observed climax even though we strive for this. The climax community description can be, and often is, revised as additional research and information becomes available (USDA 1985).

The climax plant community concept is often confounded by user needs, management considerations and individual preferences for establishing significant differences between plant communities. It isn't any wonder we are sometimes confused about what we are classifying.

SEPARATING SITES

It is important for a classification system, and to the user of basic resource data, to have consistent and standard criteria for separating and distinguishing between climax plant communities.

Criteria outlined in the National Range Handbook are as follows:

(a) Significant differences in the species or species groups that are ecological dominants in the plant community.

(b) Significant differences in the proportion of species or species groups that are the ecological dominants of the plant community.

(c) Significant differences in the total annual production of the plant community.

Any differences in criteria (a, b, and c), either singly or in combination, great enough to indicate a different use potential or requiring different management, such as different grazing systems, season of use, or stocking rate, are basis for establishing a range site (USDA 1976).

Habitat types are separated on the basis of dominant (and sometimes co-dominant) species within the climax community. Other criteria, e.g. production or composition, can be used to identify habitat type phases. The habitat type is a higher level classification with less specificity than a range site but maintaining the climax concept. A habitat type phase may be practically synonymous with a range site.

RISC proposed adding differences in soil properties, slope or topographic factors reflecting different use potentials not reflected in the plant community as criteria for differentiating sites. The authors take exception to this proposed classification criteria since it is not ecologically based. If the individual soils and associated landscape factors have been truly correlated with the site, the management differences referred to can be accounted for in soil and map unit interpretations. The only exceptions would occur when the soil or landscape is altered through erosion, mass wasting, and so forth, as reflected by the plant community.

The use of annual biomass production to quantify vegetation attributes and differentiate between sites has both advantages and disadvantages. No other attribute quantifies the consumptive value of vegetation, for grazing, wildlife forage or wood products, as well as production. Production, however, is difficult to measure with statistical precision or accuracy. Production can also be extremely variable over time, but at the same time, knowledge of the expected yearly or seasonal variability is a valuable attribute to consider in long range planning and management

Production is also an important attribute when considering condition and trend. Differences in production due to declines in plant vigor or available moisture caused by changes in soil surface characteristics (Rauzie and others 1968) can be indicative of downward trends prior to changes in basal cover or frequency of species. This is not to say that other attributes do not have additional interpretative value. Ecological sites could be classified using attributes such as cover but they would have only interpretative values associated with those parameters. A description of a combination of attributes would undoubtedly be best for interpretative purposes as well as for adequate classification.

Regardless of the criteria, the interpretation of "significant differences" depends on whether one is a "lumper" or a "splitter". Significant difference is used to describe the degree of difference for management purposes and not the degree of accuracy in the statistical or scientific sense. There is a good reason for this. As stated in the NRH, a 100 pound difference in average annual production between arid sites capable of producing only 200 to 300 pounds per acre might be considerably more significant than the same difference between sites producing 2,000 pounds per acre. The inconsistencies, however, have prompted the proposal of some additional criteria for determining what is "significant" in the site correlation process developed by the National Soil-Range Team. This process and a standard site description format as well as establishing a quality control method, are being evaluated in a four-state test.

PRESENT VEGETATION AND RANGE CONDITIONS

Range condition (USDA 1976) is determined by the coefficient of community similarity between a present community and the climax, using either the absolute production of individual species or relative compositions of the total production. The community is then classified into one of four range condition classes determined by 25 percent increments of community similarity.

RISC also proposed four classes of present vegetation, but based these on a coefficient of community similarity to the PNC. These classes are collectively referred to as "ecological status".

Community types are an aggregation of individual communities based on similarity of specific attributes such as species composition of cover,

production, structure, etc. Huschle and Hironaka (1980) discussed the need for a community type classification and proposed a model for relating community types to a probable secondary successional pattern within habitat types. Leonard and others (1987) have also discussed the need to identify seral community types for more specific interpretations relating to range sites and range condition classes.

A PROPOSAL

Different levels of classification become apparent when comparing present vegetation to the site climax community (actually site climax community type in most cases). All have value depending on the level of interpretation desired. Hironaka (1986) proposed a unifying scheme giving land managers the benefit of three levels - community type, range site (or ecological site) and habitat type. Range condition classes or ecological (seral) status could be easily integrated in this scheme. It seems immensely profitable to combine our knowledge gained through use of each system. So why doesn't this happen?

Although there might be some initial "fit" problems (the boxes we have constructed independently for classification may have to be shifted a bit to accommodate overlaps or gaps between systems), there appears to be no technical reason why this couldn't be done. It appears to be related more to human nature. Agency or personal "pride of ownership" is one hurdle. Comfort with a system we have already learned is another. We could continue on with a list of possible "excuses" that impede progress, but the compatibility of existing systems or even human nature may not be the biggest reason. Probably the paramount reason is the lack of a unifying force for vegetation classification and interpretation in the broader sense. The unifying force must come from, and involve, the major users of vegetation classification systems. Their continued involvement is imperative.

The situation is not unlike that experienced by pedologists prior to the formation of the National Cooperative Soil Survey (NCSS). The NCSS was formed without a charter (still) by a loosely organized group of professionals that recognized the need to maintain consistency in soil classification, correlation mapping, and interpretation and to discuss and propose needed changes or additions in classification and interpretation. The NCSS is independent of the professional organizations, the Soil Science Society of America and the Society of Soil and Water Conservation. The NCSS is now represented by each participant involved in soil survey and by the land grant universities. It is structured by state, regional and national levels so that issues can be dealt with at the appropriate level. The process of change is slow because of the complexity and size of the organization but there have been over 150 changes to Soil Taxonomy (USDA 1975) over the last ten years. The very existence of a National Soil Handbook and a revised manual is proof that it works. While the agencies and universities as cooperators have

obligated themselves to the accepted standards, they still have the opportunity to propose and, subsequently, implement change.

If we are to achieve substantive progress, we must forget all the excuses and pull together to form a National Cooperative for Vegetation Classification and Interpretation. We can mutually benefit from each others experience and knowledge irregardless of agency affiliation or professional interest (range, forestry, botany, etc.). We need to start by identifying user needs and objectives, then tailor classification to meet these needs. Representatives from NCSS have expressed their willingness to share information about their organizational efforts and procedures. Yet, those of us involved with classifying natural plant communities must reciprocate by pledging our determination to undertake and sustain an equivalent effort. Now is the time to act.

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DEVELOPMENT OF FORAGE RATING GUIDES FOR MONITORING RANGELAND CONDITION AND TREND

Leonard A. Volland

ABSTRACT: The concepts of forage monitoring and resource value rating have been proposed by the range management profession. One particular resource value rating, forage rating guidelines, is derived from plant association information and includes nonforest, forested vegetation, and community types dominated by non-native perennial species. The guidelines incorporate the effects of tree and shrub canopy closure on understory vegetation. The place of forage rating in the estimation and interpretation of trend is discussed.

INTRODUCTION

Range condition has been defined in two ways. Condition can be defined as the current productivity of a range relative to what that range is naturally capable of producing (Society for Range Management 1974). Range condition is also defined as the degree that current species composition comprises the composition expected in climax (Dyksterhuis 1949). The ecological precept underlying range condition classifications, whether they are based on productivity or species composition, is that vegetation is a product of its environment. This apparent cause-effect relationship between the environment and the vegetation provides the predictability necessary to conduct range inventories and to develop land management plans and monitoring efforts.

Stoddard and Smith (1955), in their classic range management text, stated "no universally accepted basis for vegetation analysis has been developed for the determination of range condition." Dorothy Brown (1954) felt the subject of range condition was in a "formative and controversial stage." Thirty years later, little agreement exists on a methodology for the evaluation of range condition, or for that matter, whether range condition has usefulness in solving today's grazing problems (Anderson and Holte 1981; Bonham 1983; Dyksterhuis 1985; Floyd and Frost 1987; Meeker and Merkel 1984; Smith 1978; Wilson and Tupper 1982).

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The reason for part of this professional disparity is that range condition is a concept that integrates many variables. Variables such as forage production, soil surface protection, soil erodability, successional trends, species composition of mixed stands, and canopy coverage effects are so intertwined that univariate measurement and analysis seldom provide a workable basis for evaluation of range condition. In part, the controversy focuses on the ecological philosophies of investigators and the original definition, which related current vegetation back to the historical standard of native vegetation or what is meant by "naturally capable."

This paper discusses some of the conceptual problems associated with the evaluation of range condition as defined by species composition and illustrates a procedure for removing some of the variability in approach while lending flexibility to the method.

THE ECOLOGICAL STATUS AND RESOURCE VALUE RATING CONCEPT

Historically, the condition of the range has been evaluated according to the potential of the site to produce forage or to provide a given species density and composition in climax. There has been a progressive development in the use of ecological stratifications for evaluating range condition ever since the incorporation of climax vegetation as a standard by the Soil Conservation Service in 1935 and the clarification of range condition definitions (Dyksterhuis 1949). Experience has indicated the range condition concept appears less appropriate to forested range where the composition of understory vegetation can be a result of ungulate grazing or tree canopy closure or both (Brown 1954; Dyksterhuis 1985). The concept of ecological potential is also difficult to apply where species normally present at climax are successfully replaced by naturalized non-native vegetation. Examples are Kentucky bluegrass (*Poa pratensis* L.) replacing tufted hairgrass (*Deschampsia caespitosa* L.) in a riparian site, or cheatgrass (*Bromus tectorum* L.) replacing bluebunch wheatgrass (*Agropyron spicatum* Scribn. & Smith) in an upland grassland community. Here the naturalized vegetation could never rate better than fair condition under the current-to-potential climax concept based on species composition. But the naturalized vegetation could rate higher using the productivity approach if condition is a direct reflection of production.

Over the last several years a concerted effort has been made by the range management profession

(Society for Range Management 1983) to clarify the range condition concept by proposing the concepts of ecological status and resource value rating.

Ecological status is the relationship of species density and composition to that expected as natural potential in the absence of human-instigated disturbances such as ungulate grazing, excessive recurrent burning, or logging. Ecological status is commonly associated with the stages of community succession as early, mid- and late-seral, and climax.

Resource value rating is the value of the current vegetation with respect to a particular use or benefit. The particular use or benefit is identified (for example, forage for livestock, forage or habitat for wildlife, riparian habitat for fish, recreation for people) and the current vegetation is rated according to what is considered best for the particular resource. The resource value may or may not parallel the successional stages of the ecological status concept. For example, where Kentucky bluegrass has invaded a site previously occupied by a climax dominant like tufted hairgrass, the ecological status may be mid-seral when considering the place bluegrass fits in the seral development to hairgrass under no livestock grazing. However, when bluegrass is evaluated as a forage resource, the stand could rate good to excellent if bluegrass expresses the vigor, composition, and production considered as that species' potential for that site. Another example is the revegetation of a site with crested wheatgrass after the elimination of sagebrush and juniper. Here a non-native species is prescribed so the forage value rating for livestock is improved.

The yardstick for measuring resource value rating can change from one resource to another. Forage value may be based on palatability of vegetation to a particular animal, for example, cattle or sheep, elk or deer. Recreational value may be different for dune buggies compared to value to backpackers or horse users. The relationship of current vegetation to natural potential and resource use becomes more apparent when ecological status is discussed concurrently with resource value (Anderson 1986; Hann 1986).

DEVELOPMENT OF FORAGE RATING GUIDES

Forage rating guides are a resource value rating system that provide numerical and qualitative data on forage as a resource for wild and domestic ungulates. The rating can be based on species density, frequency, composition, production, and/or species presence-absence. Although the guides as described here are primarily used to rate vegetation condition for ungulates as reflected in species composition, the information and concept can also be incorporated into a rating system for watershed protection, wildlife or fish habitat, and foreground visual quality.

The assumption is that any detrimental influence of ungulate grazing is reflected by a decline in the resource value. These ratings are often expressed as classes such as excellent, good,

fair, poor, or very poor. The number of classes is determined by the statistical variability in the data as illustrated by Hall (1983). The wider the confidence interval around the mean, the more variable the data and the fewer classes possible. For instance, data collected by using the loop frequency procedure in south-central Oregon indicated forage hits were more variable with respect to their mean, as measured by the coefficient of variation, than was forage composition (table 1). Four forage classes rather than five were used to rate the forage because of the variation expressed between forage guides and between attributes within guides. Forage here is defined as decreasers plus palatable increasers as given in Volland (1985b). Composition was measured using closest perennial methodology with the loop frequency method (Parker and Harris 1959). The mean values are the average of all two-transect clusters sampled for an association as shown under sample size.

Table 1--Statistical data on forage hits and composition by forage guide

Forage Guide	Sample Size	FORAGE HITS			FORAGE COMPOSITION		
		Mean	95% CI	CV	Mean	95% CI	CV
Pine/shrub/ fescue	42	5.5	.78	.47	90.2	2.02	.07
Pine/shrub/ needlegrass	55	.8	.23	.71	87.8	4.24	.18
Pine/shrub/ sedge	20	2.7	1.70	1.33	94.5	5.54	.13
Mixed conifer/ pinegrass	13	7.9	3.09	.69	78.1	8.94	.21

During the classification of plant associations in south-central Oregon, sample stands were selected for their homogeneity in species composition, landform, soils, and relative protection from stand disturbance agents such as recent fires, logging, or grazing. Many of these samples provided the data for good forage rating since they were relatively free from ungulate grazing impacts. Stands in lower ecological status as a result of livestock impacts were sampled in the most commonly occurring meadow, nonforest shrub, and ponderosa pine associations. The data from these grazed samples were regressed in order to adjust the class limits for any forage rating class. Sampling stands in a lower ecological status is necessary unless one wishes to assume a straight line relationship between some species attribute (that is, cover, frequency, or weight) and forage value rating. For example, when palatable species loop frequency was graphed against unpalatable species composition, the Kentucky bluegrass meadow data indicated a decline between good and fair forage rating. The data were too variable to adequately separate stands having these two forage ratings from each other. However, stands of poor forage rating could be separated from fair without difficulty (fig. 1). Forage production data from these stands show even less differentiation due to the cyclic nature of standing crop under rest (Volland 1978) and the decline in palatable biomass with a lower resource value rating.

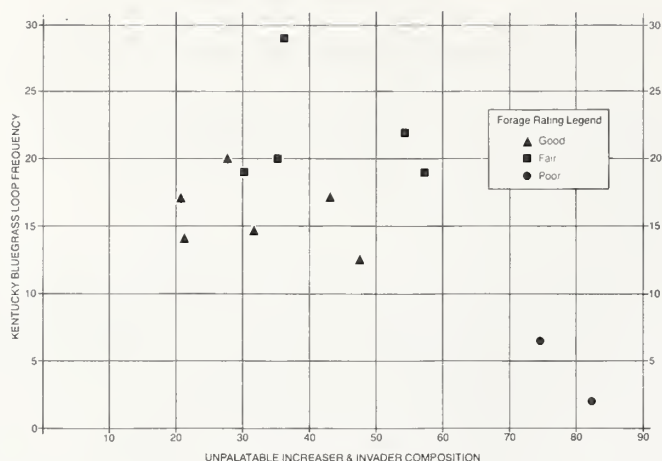


Figure 1--The relationship between Kentucky bluegrass loop frequency and unpalatable species compositions for 13 bluegrass meadows in central Oregon.

FORAGE RATING IN GRAZABLE WOODLAND

In grazable woodland¹, the sampling requirement intensifies in that density and composition of ground vegetation are affected by tree crown closure or tree stocking level as well as historical grazing patterns. As a consequence, forage rating is assessed according to the potential under existing timber stand conditions. The stand condition may be in an ecological status somewhat removed from potential natural community and the climax condition, i.e. pole-sized or immature-aged stands in mid-seral ecological status.

In this study, forage cover and composition data were regressed against tree crown cover or basal area. The forage guides displayed the forage species data by those tree overstory categories found significant during the analysis (table 2). The top of each forage class reflects the best that can be produced under the prevailing tree overstory situation given minimum grazing impacts. In south-central Oregon about 35-40 percent tree canopy was the point beyond which canopy closure had a significant impact on understory vegetation (fig. 2). This relationship has also been documented by Bartlett and Betters (1983), Hall (1966), and Pyke and Zamora (1982).

The management interpretation of a "poor" forage rating in grazable woodland is that a change in animal management is required to attain an upward trend under the prevailing tree canopy cover found

¹Grazable woodland is land on which the natural potential native vegetation is forest. The forest contains understory plants that can be grazed without significantly impairing other forest values. Rangeland is defined as land on which the native or revegetated flora is predominantly grasses, grass-like plants, forbs, or shrubs suitable for grazing or browsing (Society for Range Management 1974).

Table 2--Forage composition rating guide showing influence of tree canopy and basal area on ground vegetation composition (Volland 1985b)

Forage Guide:	Pine/Shrub/Fescue				Composition Point Rating
Tree cover:	0-35%	36-45%	46-55%	>55%	
Basal area:	0-120 ft ²	121-140	141-150	>150 ft ²	
Decreaser	81-100	73-90	57-70	41-50	53-65
&	61-80	55-72	43-56	31-40	40-52
palatable:	41-60	35-54	29-42	21-30	27-39
increaser	21-40	19-36	15-28	11-20	14-26
composition	0-20	0-18	0-14	0-10	0-13

on a particular site. A "good" forage rating implies a change in animal management will probably not result in an upward trend if the prevailing tree canopy is dense enough to impact ground vegetation. This also means that grazable woodlands will have lower species frequency and composition values in stands of dense tree cover than under an open-grown forest stand structure.

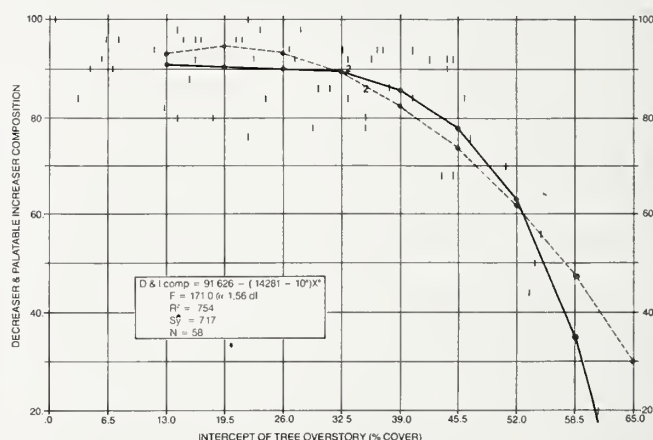


Figure 2--Relationship of decrease and palatable increase composition to tree intercept in the Pine/Shrub/Fescue forage group. Inset equation applies to bold face curve.

PLANT ASSOCIATIONS AND FORAGE RATING GUIDES

Plant associations play a key role in the development of forage rating guides. Associations form the basic structure in which vegetation data are collected, analyzed, and eventually disseminated for field use. The species density and composition data are collected and evaluated for significance by plant association. The assumption is made that the ground vegetation information collected from the minimally disturbed stands which represent an association will display little variation across that association. When differences in the data occur, the differences will be due to either differences in tree or shrub canopy closure, geographical differences within an association, or differences between two or more associations.

Initially the data are statistically analyzed for potential differences in species density and composition between associations. The lumping of species into decreaser or palatable increaser categories may mask the differences that occur in species frequency or composition between associations. Whenever nonsignificant differences occur in the data between two associations, the data from each are consolidated to form a new population for a resource value rating. A similar approach has been used by Hall (1971) on data from the Blue Mountains in Oregon to form plant associations and plant community types. As a result of this process, plant associations can be condensed to a smaller number of "resource strata," which are significantly different between themselves in the attributes being analyzed and internally homogeneous in characterization and response to ungulate management. For example, of the 61 plant associations described for the central Oregon pumice zone (Volland 1985a), 33 associations provide available forage for ungulates on a sustained basis. The 33 associations were condensed into 10 significantly different groups, five of which form the rangelands; another five groups form the grazable woodland forage rating guides (see table 3).

The plant association descriptions are used to determine which forage rating guide is appropriate for a site being evaluated. The site is first classified as to which plant association it represents using vegetation-site keys and association descriptions provided by the initial classification effort (Volland 1985a). The appropriate forage guide can then be chosen by finding the computer code associated with the correct association in table 3. Another alternative is to use a vegetation-site key that assists the user in selecting the appropriate forage rating guideline.

ECOLOGICALLY BASED CONDITION RATINGS

There have been some questions raised in the current literature regarding the applicability of ecologically based condition rating systems as a measure for evaluation of management objectives (Floyd and Frost 1987). Kentucky bluegrass, being a naturalized species, was considered as a potential natural community in this study since evidence suggests that Kentucky bluegrass will continue to dominate a meadow site even after an extensive period of complete rest (Volland 1978). Here is an example of a resource value rating being developed on the performance of a palatable increaser that is genetically and physiologically adapted to a livestock grazing regime. A rating system becomes an effective monitoring tool when potential is defined as the optimum achievable condition for a particular resource value within an ecological status that is relative to current or proposed management. The procedure of rating current vegetation to potential vegetation in climax or presettlement conditions becomes less problematic or necessary.

A comprehensive forage rating guide should stratify information by ecological status since imbedded within ecological status are variables

Table 3--Forage guides for central Oregon pumice zone with plant association identification codes represented by each guide

Rangeland

1. Deschampsia caespitosa (L.) Meadow (MM19)¹
2. Poa pratensis (L.) Meadow (MM90)
3. Poa cusickii (Vasey) Meadow (MD19-11)
4. Sagebrush/Bunchgrass (SD19-12, SD29-12, SD29-13)
5. Sagebrush/Needlegrass (SD29-14)

Grazable Woodland

1. Pine/Shrub/Fescue (CPS1-11, CPS2-11, CPS2-16, CPS2-17, CPS3-14, CLS2-14, CLS1-11)
2. Pine/Shrub/Needlegrass (CLS2-13, CLS2-11, CLS2-15, CPS2-12, CPS2-13, CPS3-11, CWS1-14)
3. Pine/Shrub/Sedge (CLS2-12, CPS2-14, CPS2-15, CPS3-12, CWC2-13, CWS1-15, CWS1-13)
4. Pine/Sedge (CLG4-11, CPG2-12, CLG4-12)
5. Mixed Conifer/Pinegrass (CWC2-12, CDS6-14)

¹Computer codes given in parentheses identify the specific plant association or community type for which the forage guide applies. Refer to Hall (1984) for a discussion of the computer coding identification process.

that affect the quantitative attributes of forage species: plant association, grazing animal preferences, tree and shrub canopy closure. Consequently, the development of forage rating guides should follow both the classification of vegetation into plant associations and the characterization of seral stages that comprise the association.

INTERPRETATION OF TREND

Trend is a change in vegetation on a specific site in relation to its forage condition rating over time. No apparent trend implies some combination of factors is resulting in a nondetectable change in condition. Downward trend implies improvement in management may be necessary. Upward trend suggests management is probably correct and improvement in forage conditions has occurred.

At the operational level an accurate estimate of trend is influenced by the inherent variability associated with biological systems and the

time-budget constraints often placed on monitoring efforts. Consequently, the manager runs the risk of either overstocking or understocking the range if an observation of no apparent trend is not true (the manager commits a Type II statistical error of accepting a false hypothesis of static trend) or if static trend is true but is rejected in favor of an assumed upward or downward trend (the manager commits a Type I statistical error). Tauke and Bonham (1985) discuss in detail the detection of trend from a statistical perspective and show the effect of sample size on the probability of committing Type I or II errors.

The major objective in trend interpretation is to determine the cause of observed trend. The cause of trend should be determined before adjustments in management are made since forage use by livestock is only one of four causes (forage use, associated vegetation, erosion, climatic factors) of observed range trend (Strickler 1968). Consequently, trend evaluation requires repeated vegetation sampling over short time intervals supplemented with measurements of animal, climate, and land treatment impacts on vegetation to discern whether observed change in trend can be affected by livestock management alone.

A forage rating is not necessary for the interpretation of the cause of trend. Assuming forage use by ungulates is the cause for an observed trend, the most a forage rating can do is suggest if an upward trend in current vegetation is feasible. For instance, a good forage rating would imply little or no trend will occur since the site is producing at or near its potential. A fair or poor forage rating implies the site is not producing to its potential and an adjustment in livestock management may improve forage.

SUMMARY

The concepts of forage monitoring and resource value rating have been proposed by the range management profession as being appropriate for addressing resource allocation questions and evaluating progress toward achievement of management objectives. One particular resource value rating, forage rating guidelines, is shown to be closely related to the range condition scorecards developed over the past 40 years. The forage rating guidelines are ecologically based in that plant associations form the basic structure from which species density and composition data are collected, analyzed, and disseminated to field units. Forage rating guidelines are developed for nonforest and forested vegetation, including communities dominated by non-native perennial species. The guidelines incorporate the effects of tree and shrub canopy closure on understory vegetation so that grazing impacts can be separated from the influence of woody vegetation when monitoring the ability of the site to provide forage for domestic and wild ungulates. The evaluation of forage rating for a specific site at different points in time provides an estimate of trend. However, a forage rating is not necessary for the interpretation of what factor(s) caused the observed trend.

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WOODLAND CLASSIFICATION: THE PINYON-JUNIPER FORMATION

Barry C. Johnston

ABSTRACT: The climax stands in the Pinyon-Juniper Formation (woodland) can be divided into two sub-formations: Juniper-Pinyon Woodland, with nine series; and Juniper Steppe Woodland, with two series. Plant associations (habitat types) have been described for most of these series. Challenges of woodland classification include lack of relict stands, properly accounting for codominance without complicating nomenclature, invasion of junipers and pinyons into adjacent ecosystems, and coordination of plant association classification with soils and landform classifications.

EXTENT OF THE FORMATION

Pinyon-juniper stands are common in the western United States, especially in the Great Basin. They comprise part of a group of stands of short trees, often called "woodland." Woodland, as a general term, describes stands of small trees "capable of forming a canopy and hence of constituting a real though low forest" (Clements 1920; also see Daubenmire 1978, Whittaker 1975). The tree canopies are often open and savanna-like, although they can be closed or nearly so.

In its original definition (Clements 1920), "woodland" is a climax classification unit, and so it should have whole climax plant associations nested within it. The Coniferous Woodland Formation (Johnston 1987) consists of climax plant communities dominated by short-stature pine species of *Pinus* sect. *Parrya*, subsection *Cembroides*, all called "pinyons" (Critchfield and Little 1966), and those dominated by several tree juniper species. There are four pinyon species and at least five juniper species that dominate climax stands in the United States (Brown 1982, West 1984, Critchfield and Little 1966). These species are shown in table 1.

Woodlands have been classified differently since they were first described by Clements; three of these classifications are shown in table 2.

The generalized distribution of all these species (except *Juniperus occidentalis* and *J. scopulorum*, discussed later) is presented in figure 1 (after Little 1971, Critchfield and Little 1966). When

Table 1--Species dominating pinyon-juniper stands in the United States

<i>Juniperus californica</i>	
<i>Juniperus deppeana</i>	
<i>Juniperus monosperma</i>	
<i>Juniperus occidentalis</i>	
<i>Juniperus osteosperma</i>	
<i>Juniperus scopulorum</i>	
	<i>Pinus cembroides</i>
	<i>Pinus edulis</i>
	<i>Pinus monophylla</i>
	<i>Pinus quadrifolia</i>

the maps of species were overlaid, there was a large degree of correlation among species. Species within the same genus often had nearly disjunct distributions (for example, *Juniperus monosperma* and *J. osteosperma*; *Pinus monophylla* and *P. edulis*). Species in different genera often had a large overlap (for example, *Pinus edulis* and *Juniperus osteosperma*). Natural species distributional groups that are apparent from figure 1 are shown in table 3.



Figure 1--Map of western North America, showing generalized distributions of the leading species within the Coniferous Woodland Formation (after Little 1971, Critchfield and Little 1966)

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Table 2--Three different classifications of the woodland climax

<u>Clements 1920</u>	<u>Daubenmire 1978</u>	<u>Johnston 1987</u>
Woodland Climax	Temperate Xerophytic Forest Region	Woodland
(Pinyon-Juniper Formation)		
Pinyon-Cedar Woodland	<u>Pinus cembroides</u>	Coniferous Woodland
(Pinyon-Juniper Assn.)	Province	Formation
	1. <u>Pinus flexilis</u> Section	1. Juniper-Pinyon Woodland
	2. <u>Pinus</u> sect. Cembroides Section	2. Juniper Steppe Woodland

The two northern juniper species, *Juniperus occidentalis* and *J. scopulorum*, occur within the range of the pinyons on cooler and higher elevation sites (Brown 1982), but seldom are they leading constituents of these woodlands. However, to the north and elevationally above the distribution of the pinyons, these two junipers dominate stands with other conifers usually not present. These two series, *Juniperus scopulorum* and *J. occidentalis*, merit recognition as a separate subformation, Juniper Steppe Woodland.

CLASSIFICATIONS AT THE HABITAT TYPE LEVEL

Not many plant association (habitat type) or other climax plant community classifications have included pinyon-juniper stands; the usual convention of "forested habitat type" studies is not to sample woodlands. We can therefore expect the classification scheme for woodlands to be incomplete. A partial sample of climax plant associations that have been described appears in table 4.

Table 3--Species groups in the Coniferous Woodland Formation. Within Subformation A, groups are listed as in figure 1

<u>CONIFEROUS WOODLAND FORMATION</u>
A. Juniper-Pinyon Woodland
1. <u>Juniperus osteosperma</u> Series
2. <u>Pinus cembroides-Juniperus</u> spp. Series
3. <u>Pinus edulis</u> Series
{ 4. <u>Pinus edulis-J. deppeana</u> Series
{ 5. <u>Pinus edulis-J. monosperma</u> Series
{ 6. <u>Pinus edulis-J. osteosperma</u> Series
7. <u>Pinus monophylla</u> Series
{ 8. <u>Pinus monophylla-J. osteosperma</u> Series
9. <u>Pinus quadrifolia</u> Series
B. Juniper Steppe Woodland
10. <u>Juniperus occidentalis</u> Series
11. <u>Juniperus scopulorum</u> Series

Table 4--Plant associations (habitat types) that have been described in the Coniferous Woodland Formation

<u>SUB-FORMATION</u>	<u>PLANT SERIES</u>	<u>PLANT ASSOCIATION</u>	<u>PHASE</u>	<u>REFERENCES</u>
A. Juniper-Pinyon Woodland				
1.	<u>Juniperus osteosperma</u> Series			
		<i>Juniperus osteosperma/Roegneria spicata</i>		Ream 1964, Fisser and others 1980
		<i>Juniperus osteosperma/Oryzopsis hymenoides</i>		
2.	<u>Pinus cembroides-Juniperus</u> spp. Series			
		<i>Pinus discolor-Quercus emoryi/Arctostaphylos pungens</i>		Moir 1979, Moir and Carleton 1987
		<i>Juniperus erythrocarpa/Bouteloua eriopoda</i>		Moir and Carleton 1987
		<i>Pinus discolor/Cercocarpus brevifolius-Rhus coriophylla</i>		Moir and Carleton 1987
		<i>Pinus discolor/Muhlenbergia emersleyi</i>		Moir and Carleton 1987
		<i>Pinus discolor-Quercus arizonica/Nolina microcarpa</i>		Moir and Carleton 1987
		<i>Pinus discolor/Quercus toumeyi</i>		Moir and Carleton 1987
		<i>Juniperus erythrocarpa/Quercus turbinella</i>		Moir and Carleton 1987
3.	<u>Pinus edulis</u> Series			
		<i>Pinus edulis/Andropogon hallii</i>		Moir and Carleton 1987
		<i>Pinus edulis/Artemisia nova</i>		De Velice and others 1986
		<i>Pinus edulis/Cowania mexicana</i>		Baker 1984, Moir and Carleton 1987
		<i>Pinus edulis/Fallugia paradoxa</i>		Moir and Carleton 1987
		<i>Pinus edulis/Festuca arizonica</i>		Merkle 1952, Moir and Carleton 1987

4. Pinus edulis-Juniperus deppeana Series

- | | |
|---|--------------------------------------|
| Pinus edulis/Arctostaphylos pungens | Moir and Carleton 1987 |
| Pinus edulis-Quercus emoryi/Arctostaphylos pungens | Moir and Carleton 1987 |
| Pinus edulis-Juniperus deppeana/Bouteloua gracilis | Moir and Carleton 1987 |
| Juniperus deppeana/Bouteloua gracilis | Moir and Carleton 1987 |
| Pinus edulis-Juniperus deppeana/Bouteloua gracilis | Kennedy 1983, Moir and Carleton 1987 |
| Pinus edulis-Juniperus deppeana/Cercocarpus montanus | Moir and Carleton 1987 |
| Juniperus deppeana-J. monosperma/Cercocarpus montanus-Ceanothus greggii | Moir and Carleton 1987 |
| Pinus edulis-Juniperus deppeana/Muhlenbergia dubia | Kennedy 1983, Moir and Carleton 1987 |
| Juniperus deppeana/Muhlenbergia emersleyi | Moir and Carleton 1987 |
| Juniperus deppeana/Panicum obtusum | Moir and Carleton 1987 |
| Pinus edulis/Quercus turbinella | Moir and Carleton 1987 |
| Juniperus deppeana-Quercus grisea/Rhus aromatica ssp. trilobata | Moir and Carleton 1987 |
| Pinus edulis-Quercus emoryi/Rhus aromatica ssp. trilobata | Moir and Carleton 1987 |

5. Pinus edulis-Juniperus monosperma Series

- | | |
|---|---|
| Juniperus monosperma/Agave lechuguilla | Moir and Carleton 1987 |
| Juniperus monosperma/Andropogon hallii | Moir and Carleton 1987 |
| Pinus edulis-Juniperus monosperma/Bouteloua curtipendula | Baker 1984 |
| Pinus edulis-Juniperus monosperma/Bouteloua gracilis | Jameson 1966, Wright and others 1973, Shepherd 1975, Brown 1982, Kennedy 1983, Francis 1986, Moir and Carleton 1987 |
| Juniperus monosperma/Bouteloua gracilis | Wright and others 1973, Francis 1986 |
| Phase Quercus turbinella | Moir and Carleton 1987 |
| Pinus edulis-Juniperus monosperma/Cercocarpus montanus | Kennedy 1983, Moir and Carleton 1987 |
| Phase Ribes cereum | Baker 1984 |
| Juniperus monosperma/Elytrigia smithii | Arnold 1964, Francis 1986 |
| Juniperus monosperma/Fallugia paradoxa | Moir and Carleton 1987 |
| Juniperus monosperma/Larrea divaricata | Moir and Carleton 1987 |
| Pinus edulis-Juniperus monosperma/Muhlenbergia pauciflora | Kennedy 1983, Moir and Carleton 1987 |
| Juniperus monosperma/Muhlenbergia pungens | Moir and Carleton 1987 |
| Juniperus monosperma/Nolina microcarpa | Moir and Carleton 1987 |
| Juniperus monosperma/Quercus undulata | Moir and Carleton 1987 |
| Pinus edulis-Juniperus monosperma/Stipa nelsonii | Kennedy 1983, Moir and Carleton 1987 |
| Juniperus monosperma-Pinus edulis/Stipa neomexicana | Baker 1984 |
| Juniperus monosperma-Pinus edulis/Stipa scribneri | Baker 1984 |

6. Pinus edulis-Juniperus osteosperma Series

- | | |
|---|---|
| Pinus edulis-Juniperus osteosperma/Amelanchier utahensis-Cercocarpus montanus | Hess and Wasser 1982, Baker 1983, Madany and West 1984 |
| Phase Arctostaphylos patula | Baker 1983, Madany and West 1984 |
| Phase Carex pityophila | Baker 1984 |
| Phase Roegneria spicata | Baker 1982 |
| J. osteosperma-Pinus edulis/Artemisia nova | Baker 1984 |
| Phase Roegneria spicata | Baker 1984 |
| Pinus edulis-Juniperus osteosperma/Artemisia tridentata | Rasmussen 1941, Tiedeman 1978, Brotherson and others 1983, Moir and Carleton 1987 |
| Phase Bouteloua gracilis | Brotherson and others 1983 |
| Pinus edulis-Juniperus osteosperma/Bouteloua gracilis | Moir and Carleton 1987 |
| J. osteosperma-Pinus edulis/Cercocarpus ledifolius | Baker 1984 |
| Pinus edulis-J. osteosperma/Cercocarpus montanus | Erdman 1970, Greenwood and Brotherson 1978, Moir and Carleton 1987 |
| Phase Elymus salinae | Baker 1984 |
| Phase Roegneria spicata | Baker 1984 |
| Phase Quercus gambelii | Moir and Carleton 1987 |
| Phase Quercus undulata | Moir and Carleton 1987 |
| Juniperus osteosperma/Cercocarpus montanus-Peraphyllum ramosissimum | Hess and Wasser 1982, Baker 1983 |
| J. osteosperma-Pinus edulis/Cowania mexicana | Brown 1982, Baker 1984 |
| Juniperus osteosperma/Elymus salinae | Baker 1982 |
| J. osteosperma-Pinus edulis/Hilaria jamesii | Baker 1984 |

Juniperus osteosperma/Hilaria mutica
Phase Artemisia tridentata
Pinus edulis-Juniperus osteosperma/Mahonia fremontii
Pinus edulis/Muhlenbergia pungens
J. osteosperma-Pinus edulis/Oryzopsis hymenoides
Pinus edulis-Juniperus osteosperma/Poa fendleriana
Pinus edulis-Juniperus osteosperma/Purshia tridentata
Pinus edulis-Juniperus osteosperma/Quercus gambelii
Juniperus osteosperma-Pinus edulis/Roegneria spicata
Juniperus osteosperma/Stipa neomexicana

Moir and Carleton 1987
Mason and others 1967, Komarkova 1986
Moir and Carleton 1987
Baker 1984
Erdman and others 1969, Baker 1982-4, Moir and Carleton 1987
Erdman and others 1969, Austin and others 1984, Baker 1984, Moir and Carleton 1987
Merkle 1952, Mason and others 1967, Steinhoff 1978, Hess and Wasser 1982, Baker 1984, Moir and Carleton 1987
Harniss and West 1973, Fisser and others 1979, Baker 1983
Moir and Carleton 1987

7. Pinus monophylla Series

8. Pinus monophylla-Juniperus osteosperma Series

Pinus monophylla-J. osteosperma/Amelanchier pallida
Pinus monophylla-J. osteosperma/Artemisia nova
Pinus monophylla-J.osteosperma/Cercocarpus ledifolius
Pinus monophylla-J. osteosperma/Cowania stansburyana
Pinus monophylla-J. osteosperma/Festuca idahoensis
Pinus monophylla-J. osteosperma/Purshia tridentata
Phase Festuca idahoensis
Pinus monophylla/Quercus turbinella
Pinus monophylla/Quercus turbinella-Arctostaphylos pungens
Phase Quercus emoryi

Young and others 1976
Beatley 1979, Everett and others 1983
Young and others 1976
Young and others 1976
Everett and Sharrow 1985
Young and others 1976
Everett and others 1983
Moir and Carleton 1987
Moir and Carleton 1987
Moir and Carleton 1987

9. Pinus quadrifolia Series

Pinus quadrifolia-Juniperus californica

Brown 1982

B. Juniper Steppe Woodland

10. Juniperus occidentalis Series

11. Juniperus scopulorum Series

Juniperus scopulorum/Artemisia tridentata
Juniperus scopulorum/Cercocarpus montanus
Juniperus scopulorum/Muhlenbergia filiculmis
Juniperus scopulorum/Oryzopsis micrantha
Juniperus scopulorum/Purshia tridentata
Juniperus scopulorum/Quercus gambelii
Juniperus scopulorum/Roegneria spicata
Juniperus scopulorum/Schizachyrium scoparium

Hess 1981, Baker 1984, Hess and Alexander 1986
Hess 1981, Baker 1984, Hess and Alexander 1986
Baker 1984
Nelson 1961, Hansen 1984, Girard 1985, Hansen and Hoffman 1986
Hess 1981, Baker 1984, Hess and Alexander 1986
Baker 1984
Brown 1971, Terwilliger and Tiedeman 1978, Baker 1984, Hansen and Hoffman 1986, Tiedeman and others 1987
Baker 1984

CHALLENGES IN CLASSIFICATION

A mixture of tree species is common to most stands, especially within the Juniper-Pinyon Woodland. Codominance is the rule in woodlands, rather than the exception. This causes some difficulties in nomenclature, challenging us to maintain distinctions among plant associations on really different sites, while at the same time

using an uncomplicated nomenclature, and grouping associations into series based on their close relationships.

Even though the distinctions among tree species are fairly sharp, as shown above, it is not difficult to find stands with similar environments and understory species, that range from nearly complete pinyon dominance to nearly complete

juniper dominance. Multiple species names as series names seems inevitable; for example, a series comprising all the plant associations with Pinus edulis dominant would be highly artificial and too broad.

At the same time, stands dominated by juniper may in some cases be closely related to stands dominated by pinyon. Separating them into separate series may be just as artificial.

In many places, junipers and pinyons have invaded adjacent shrubland or grassland in historical times. This has been especially dramatic with Juniperus occidentalis. The classification must cover all types within the study area, and be correlated with soils and landform, and the key must include abiotic as well as biotic characters, so that these invasions can be detected.

One of the most important uses of a climax classification system is shown by the considerable utility of habitat types to provide the most significant stratification of the land surface (Daubenmire 1952). This stratification apparently is applicable to juniper-pinyon woodlands, just as it is to every other formation, but is often hampered by the difficulty of finding stands at or near climax.

Many of these stands have been intensively grazed by livestock, which has had widespread effects. The sites are often sensitive to grazing use, and apparently recover slowly or not at all. This situation can make it difficult to find relict stands, and make stands difficult to identify to climax type. In some areas, there may be only 3 to 5 percent of the acres of a habitat type that are recognizable as to type on vegetation criteria (Baker 1982). From a classification point of view, it becomes critical to correctly assess the past history of a stand.

At the same time, many juniper-pinyon habitat types are correlated with soils, landform, or geology, and more use needs to be made of these criteria when delineating plant associations and writing keys. The greatest progress is being made in situations where site characters are used to describe species and association distribution. This is remarkably appropriate for a science whose roots is in the indicator plant concept of Clements (1920).

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SHRUB-STEPPE CLASSIFICATION IN THE WESTERN UNITED STATES

Edwin W. Tisdale

ABSTRACT: Classification of shrub-steppe ecosystems has progressed greatly as the result of studies during the past three decades. Currently, classification on the habitat type model has been developed for much of the region, and the recognition of range (ecological) sites within habitat types has increased the value of the system for management. The major need for future study is a better understanding and classification of seral vegetation in the type.

INTRODUCTION

The term shrub-steppe is a purely descriptive one, denoting a group of natural communities in which a shrub layer is associated with one or more herbaceous layers, usually dominated by perennial grasses. This broad category includes several communities of major importance in the wildlands of the Intermountain and Northwestern regions of the United States and adjacent areas in southwestern Canada.

The most extensive type is the sagebrush-steppe, with a shrub layer dominated by woody species of sagebrush (*Artemisia*), and occupying some 143 M acres (58 M ha) (Branson and others 1967). The other major type is the shadscale or salt-desert shrub, with an estimated area of 38 M acres (17 M ha) and a shrub layer dominated by species of *Atriplex* and other members of the goosefoot (*Chenopodiaceae*) family. Only a portion of this type can be confidently designated as shrub-steppe, with significant herbaceous layers. Other communities consist of nearly pure stands of one or more of the shrubby *Chenopods*, and the prior existence of an herbaceous layer in these cases is a matter of conjecture.

Smaller communities of shrub-steppe are dominated by species of rabbit brush (*Chrysothamnus*), wild buckwheat (*Eriogonum*), snowberry (*Symphoricarpos*), antelope bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus*), and others. I know of no reliable estimate for the area occupied by such types, but they are sizable and important in many localities.

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Shrub-steppe communities collectively represent a major wildland resource in the area under discussion. Historically, their major value has been perceived as a grazing resource for domestic livestock and as habitat for a variety of wildlife. More recently, the watershed influences and recreational values of these lands have also come to be appreciated (Blaisdell and others 1982).

CLASSIFICATION-CONSTRAINTS

Early classifications of shrub-steppe types were so broad as to be almost meaningless. In the early 1950s, Billings (1951) noted the lack of basic synecological knowledge for these communities. Great progress has been made since this time, but much remains to be done. To understand the slow development and currently incomplete state of classification, one must consider certain factors that have slowed the progress of ecological understanding. I will use sagebrush vegetation as a prime example of this situation, but most of my remarks apply equally to other shrub-steppe communities.

The most important inhibiting factor for ecological study has been the severe and widespread disturbance resulting from grazing by domestic livestock. Grazing pressure prior to white settlement appears to have been relatively light (Butler 1976) and the native forage species were not well adapted for the concentrations of domestic livestock that appeared in the 1800's. The result was a marked decline in native grasses and other palatable species, and their replacement by more grazing-tolerant species. The extent of range deterioration was sufficient to arouse official concern by the turn of the century (Kennedy and Doten 1901; Griffith 1902), but several more decades passed before serious efforts were made to control grazing use. By this time, much of the vegetation had come to consist of dense stands of sagebrush, with a sparse herbaceous understory consisting mainly of introduced annuals such as cheatgrass (*Bromus tectorum*). The main exception to this type of cover was in areas where fire had killed most of the sagebrush and produced an annual grassland type.

These changes in vegetation contributed strongly to a perception of the sagebrush type as a form of desert. This concept is evident in the description and illustration of the type by Shantz and Zon (1924), which depicts a thoroughly depleted stand with abundant sagebrush and a

sparse understory of exotic annuals. Their designation of the type as "sagebrush desert" or "northern desert shrub" became widely accepted and is perpetuated by the equally inappropriate term "cold desert."

This view of the sagebrush-steppe as a uniform desert type, coupled with the scarcity of relatively undisturbed stands, combined to discourage serious ecological investigation at a time when many other wildland communities were being studied in some detail.

A second factor inhibiting ecological understanding of the sagebrush-steppe was the great geographical extent and ecological variation of the type. Geographically it extends from southwestern Canada south nearly to the Mexican border, and from points close to the Pacific coast east to western North and South Dakota. The type occurs at elevations ranging from near sea level to 10,000 feet (3,050 m) or more, with annual precipitation from 6 to 30 inches (150-750 mm) and comparable differences in temperature regimes. Differences in vegetation are equally great, as shown by many recent studies (Hironaka 1979).

A third factor affecting progress has been the scarcity of taxa that are sufficiently narrow in ecological amplitude to serve as reliable indicators of specific ecosystems. The principal grasses of the herbaceous layer, such as bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), and Sandberg bluegrass (*Poa secunda*) exhibit strong ecotypic variation (Tisdale and Hironaka 1981), but lack corresponding morphological differences that can separate populations in the field. Some of the associated forbs are fairly restricted in distribution, but often their frequency of occurrence is too low and/or irregular to have indicator value.

The best indicator species have proved to be the many kinds of sagebrush occurring in the region. The taxonomic section (*Tridentatae*) of *Artemisia*, which includes the woody species, is described as "a complex in a dynamic state of expansive evolution and hybridization" (Shultz 1984). Investigations during the past 35 years, including those of Ward (1953), Beetle (1960), Beetle and Young (1965), Winward (1970, 1980), and Goodrich and others (1985), have clarified relationships and revealed the presence of a number of previously unrecognized taxa within this complex. Fortunately for ecologists and land managers, these taxa have proven to be ecological as well as taxonomic entities, with each one adapted to a special set of conditions within the sagebrush ecosystem. The result has been the development of a number of stable communities, each dominated by a single taxon of sagebrush and differing in its herbaceous vegetation. At least 14 recognized kinds of sagebrush now fill this role of dominants, and given the variability within the group, it is likely that additional taxa will be recognized in the future.

CLASSIFICATION--PROGRESS AND CURRENT STATE

Serious attempts at classification of the sagebrush-steppe date from the mid-1950's. They involved detailed study of relatively undisturbed stands, along with investigation of the physical

and biotic factors affecting them (Poulton and Tisdale 1961). Much of the early work was supported by Hatch Regional Project W-25, which provided funds for community studies within Oregon, Washington, and Idaho and for the taxonomic studies of Beetle (1960). The habitat type and series concepts, developed first for forest vegetation (Daubenmire 1952), proved applicable to sagebrush and other shrub-steppe vegetation and have been applied widely.

Significant progress in classification of sagebrush-steppe vegetation has been made in Washington (Daubenmire 1970), Oregon (Eckert 1958; Tueller 1962), Idaho (Hironaka and others 1983; Schlatterer 1972; Tisdale and others 1965), Montana (Mueggler and Stewart 1980), Wyoming (Brodahl 1977), Nevada (Jensen and Peck 1986; Zamora and Tueller 1977), and Colorado (Francis 1983). Hugie and others (1974) have also described sagebrush communities in Idaho, Utah, and Nevada. Several sagebrush habitat types have been recognized in southern British Columbia (McLean 1970).

In the application of this system to the sagebrush-steppe, each *Artemisia* taxon forms a series, and each series contains one to several habitat types, which differ in the composition of their herbaceous layers. For example, in Idaho, basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) is the dominant shrub for a series that includes four recognized habitat types, with the herbaceous layer dominated by bluebunch wheatgrass, needle-and-thread (*Stipa comata*), Idaho fescue, and Basin wild rye (*Elymus cinereus*), respectively. These communities all occur on relatively dry sites with deep, well drained soils, but differ in other site characteristics such as soil texture, topography, and so on. The fact that subspecies as well as species of sagebrush form distinct series attests to the ecological differences among these taxa.

Most of these communities are regional in distribution. Three of the four big sagebrush habitat types listed above have also been recognized in Oregon, Washington, British Columbia, Nevada, and Montana. Similarly, low sagebrush (*Artemisia arbuscula* ssp. *arbuscula*), forms habitat types with bluebunch wheatgrass and Idaho fescue in Idaho and most of the states listed above. Habitat types of the same name in widely separated areas are readily recognizable in the field and possess many vegetational and site characteristics in common.

Sagebrush habitat types also exhibit a large amount of internal variability. This is often evidenced more in productivity of the vegetation than in botanical composition, and is related to variations in site characteristics. Such differences in vegetation and site provide the basis for further stratification into range or ecological sites. These finer divisions form the basis for management in many areas, and where recognized as subdivisions of known habitat types, they can provide good measures of ecosystem potential. Currently range sites described in the tri-state area of Idaho, Oregon, and Washington are related to habitat types, as shown in table 1.

As indicated in table 1, Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) forms a series in which Wyoming big sagebrush/bluebunch wheatgrass

Table 1--Sagebrush-steppe vegetation in southern Idaho classified to series, habitat type, and range site levels

Series Dominant	Habitat type	Production lb/acre	Range Site
<i>Artemisia tridentata</i>			
ssp. <u>wyomingensis</u>	ARTRW/AGSP	450	B11-4-1 Shallow Loamy
ssp. <u>wyomingensis</u>	ARTRW/AGSP	600	B11-5-1 Stony
ssp. <u>wyomingensis</u>	ARTRW/AGSP	400	B11-8-1 South Slope
ssp. <u>wyomingensis</u>	ARTRW/AGSP	750	B11-1-1 Loamy
ssp. <u>vaseyana</u>	ARTRV/Feid	1,200	D25-22-1 Loamy
ssp. <u>vaseyana</u>	ARTRV/Feid	1,800	D25-23-1 North Slope

is a common type. Four range sites, distinguished by differences in productivity, soil, and topographic characteristics have been recognized, and further study may reveal more. All occur within areas of low precipitation (250-300 mm) with relatively shallow, and/or rocky soils. A similar situation occurs with a more mesic subspecies, mountain big sagebrush (*A. tridentata vaseyana*) where mountain big sagebrush/Idaho fescue constitutes a widely distributed and productive association that contains at least two range sites.

A major problem currently limiting broad application of vegetational classification is scarcity of information regarding seral vegetation in the sagebrush-steppe type. The effort required to study undisturbed sites has usually not been extended to the successional stages within these types yet most sagebrush vegetation is in some seral stage. Evaluation of the potential of depleted stands requires the ability to place them within their correct habitat type, and even range site. This should be possible based on the combined use of vegetational and site factors.

In the case of the vegetation, much more information is needed concerning the successional stages that develop from disturbance within each habitat type. Huschle and Hironaka (1980) have proposed a cone model that relates the several seral communities produced by disturbance to the climax community. Preliminary studies (Hann 1982) indicate the possibilities of this approach, but its application to shrub-steppe vegetation needs to be tested. One constraint for study of seral stands of sagebrush-steppe is the slow rate of succession, even after the apparent disturbing factors are removed or greatly modified. Lack of a seed source for the climax herbaceous species, the inertia produced by dominance of an existing stand by long-lived shrubs, and selective grazing of sparse stands of palatable herbaceous species by native rodents and rabbits appear to be the principal factors responsible for this phenomenon.

Another factor affecting some seral stands is the great masking of community differences by the widespread dominance of introduced species such as cheatgrass. Fortunately, another characteristic of sagebrush communities can be helpful in the study of seral stands. Since most sagebrush species are low in palatability to livestock, the shrub layer usually remains on depleted areas, and can provide identification of the type to series level. This grouping gives a measure of site potential. Although this is not as valuable as identification to habitat type or range site, it is useful for many purposes, including evaluation for sagebrush control and range revegetation (Johnson 1987).

Alternatively, depleted stands may also be classified based on their site characteristics, especially soils. Since both vegetation and soils are products of the ecosystem, the relationship between their classification units should be strong. In practice, the correlation between soils and vegetation has frequently been found to be rather weak (Daubenmire 1970; Hugie and others 1974; Jensen and Peck 1986). Much of this lack of correlation may be due to the imperfect state of vegetation and soil classification in shrub-steppe types; this situation should improve with further study. Another promising approach used successfully in grasslands (Tisdale and Bramble-Brodahl 1983) is available through analysis of the combined effects of a group of site factors, which can be measured by techniques such as discriminant analysis. An example of this is reported by Jensen and Peck (1986) for sagebrush-steppe vegetation in northern Nevada. The authors found strong relationships between plant communities and a group of soil characteristics that included profile depth, subsoil clay content, and total rock content.

CONCLUSIONS

Appraisal of the current status suggests that classification of shrub-steppe vegetation by the habitat type or association approach is a useful tool in resource appraisal and management. Data on the associated soil and other site characteristics are an essential part of this ecosystem classification, particularly where so much of the vegetation is in seral stages.

The development of workable classifications in the shrub-steppe has proved to be directly dependent on the ecological (and taxonomic) data available, and thus on the quantity and quality of supportive research. Meaningful classification has come as a logical outgrowth from basic understanding of the vegetation. Skills for application of these systems in the field must also be considered. Accurate identification of plant species is essential, and in some cases, such as the subspecies of big sagebrush, requires considerable training and experience. Similarly, some of the soil differences among sagebrush communities are not readily apparent without considerable knowledge.

Future needs include extension of classification into geographical areas and communities where it has not been actively pursued, and refinement of existing schemes in the light of increased knowledge. The biggest challenge, however, is that of developing a better understanding and a workable classification of ecosystems supporting seral vegetation.

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USING HABITAT CLASSIFICATION SYSTEMS IN UPLAND GAME BIRD HABITAT

Donald A. Klebenow

ABSTRACT: Patterns of sage grouse habitat use often correspond with delineations of range or ecological sites. Information of this type is of value to resource managers because it identifies which ecological sites are important for management of wildlife such as sage grouse. Since range site descriptions are of climax vegetation and the habitat that upland game prefer may not be climax, it is desirable that site descriptions include descriptions of the site's seral stages.

INTRODUCTION

The systems of land classification based on vegetation devised by range and forest ecologists provide a language that facilitates communication between wildlife habitat researchers and other researchers and managers. These classifications serve two purposes: describing the setting of research study areas and projecting applications of research findings to areas of similar capabilities (Hironaka 1984).

Wildlife researchers have used a variety of systems. For a very general habitat or study area description Kuchler's (1964) potential natural vegetation classification has sometimes sufficed. His classification is extensive in its treatment, covering the entire United States. The vegetation types are too broad to be very useful in habitat description and in the Great Basin where I work the vegetation classification for all my study areas would be sagebrush steppe. But that would include the habitat of sage grouse (Centrocercus urophasianus) and chukar partridge (Alectoris graeca) plus part of the habitat of California quail (Lophortyx californica) and blue grouse (Dendragapus obscurus). It is useful only in very general terms.

A more specific classification has been presented by Dealy and others (1981) in *Wildlife Habitats in Managed Rangeland--The Great Basin of Southeastern Oregon*. They

recognize the various species and subspecies of genus Artemisia and present 11 vegetation types dominated by sagebrush within Kuchler's (1964) sagebrush steppe classification. Twenty-eight plant community types are used to describe Oregon's rangelands. They are identified mainly by tree and shrub dominant species and in some cases, dominant grass species in the understory. Their use is to explain the relationship of terrestrial vertebrates to plant communities in southeastern Oregon (Maser and others 1984a, 1984b).

The Dealy and others (1981) classification approximates the habitat type classification of Daubenmire (1952) and others (Mueggler and Stewart 1980; Hironaka and others 1983). In some cases Dealy and others (1981) are more general than the habitat type classification, for example, the basin big sagebrush/bunchgrass community where the grasses are not specifically identified. Others of their community types parallel the habitat type concept as the communities are more specifically named. The western juniper/big sagebrush/Idaho fescue community is one such case. It is unfortunate that they used the more general classification in part. It would be desirable if habitat types would become accepted as the standard for plant community classification, thus the system by which other classifications would be compared.

EXPERIENCE WITH SYSTEMS

I personally first used habitat types to classify and describe a mule deer winter range in western Montana (Klebenow 1962). Within the Pseudotsuga menziesii/Physocarpus malvaceus and Pinus ponderosa/Physocarpus malvaceus habitat types of the study area there were sites that differed in plant composition and abundance that related to more or less use by mule deer than other sites. Thus, it was necessary to divide the habitat into units more homogeneous than the two habitat types. I did that and eventually outlined 13 different vegetation community types based on differences in plant composition and plant density. The point is, in order to adequately describe the use of habitat types by wildlife, it was necessary to subdivide the habitat types into more uniform units.

Since that time, the range site or ecological site concept have also been developed to classify habitats into more homogeneous units. The Bureau of Land Management and the Soil

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Conservation Service are two Federal agencies using these classifications. Their use is increasing.

Range or ecological sites were used for basic habitat inventory on two sage grouse studies with which I have been associated. These site classifications have great potential for use in wildlife habitat management, for patterns of habitat use by birds often corresponded with delineations of range sites. On the Saval Ranch in northeastern Nevada all the strutting grounds were located within the Loamy, 8-10 Inches Precipitation Zone Range Site, 1 of 17 range sites on the study area. In northwestern Nevada on the Sheldon National Wildlife Refuge four upland ecological sites and one meadow site contained virtually all the habitat used by sage grouse. In total 28 ecological sites were identified and mapped on the entire refuge. On the uplands the birds used the ecological sites that contained a combination

of Wyoming big sagebrush (A. tridentata wyomingensis) and low sagebrush (A. arbuscula). Monotypic stands of either shrub species were seldom used except during the winter. During the winter the mixed species sagebrush sites were used but the monotypic sagebrush Ecological Site 690, Arid Loamy Terrace (table 1) provided sagebrush forage when sagebrush on higher elevation sagebrush sites was not available due to snow cover. This site was used only during the winter months.

These studies were not done to test the relationship between sage grouse habitat selection and ecological site classification, but the relationship was obvious when the bird habitat use was evaluated and compared to range site inventory maps.

Table 1--Ecological site description of Arid Loamy Terrace, Ecological site 690, High Desert Resource Province, Shrub Climax Type (Upland). The location of the typical example is Sec. 13, T34S, R27E, Hart Mountain National Wildlife Refuge, Lake County, OR (Anderson 1978)

ARID LOAMY TERRACE

Physiography: This site occurs on nearly level to gently sloping basin terraces. Slope gradients vary from 2 to 6%. Elevation is about 4,500 to 5,500 feet (1570-1675 meters).

Climate: Precipitation averages 8 to 11 inches (20-28 cm) most of which comes in October through June as snow and spring-autumn rain. About 30% of the total precipitation comes during the growing season which begins about April 1 and ends about July 1. The growing season is relatively cold, being typical for the High Desert Province which has average mean minimum/maximum temperatures for April 29/60 °F (-.7/15.6 °C); May 35/67 °F (1.7/20 °C); June 40/74 °F (4.4/23 °C). Recharge of available soil moisture begins in November but the average daytime temperature at that time is below 39-40°F (4°C) and there usually is little or no autumn regrowth on this site.

Soils: The soils on this site have loamy surface layers and loamy to moderately fine textured subsoils. They are gravelly throughout and the subsoil may be stony. They are underlain by hardpan or cemented gravel and stones at a depth of about 18 inches (46 cm). The significant soil series include: Olson loam.

Original Native (climax) Vegetation: Species commonly found on this site which did not occur in the climax stand are listed and marked 0 in occurrence.

Approximate Percent Ground Cover

Bare ground 10-20% Mosses & Lichens T (Trace) Gravel, stone, rock 10-20% Total
vegetational cover is about 70-80%

Grasses (max 50%)

Bluegrass, Sandberg	2
Brome, cheatgrass	0
Needlegrass, Thurber	2
Ricegrass, Indian	15
Webber	5
Squirreltail	5
Wheatgrass, bluebunch	20
foxtail	T
streambank	2

Forbs (max 5%)

Buckwheat, snow	1
Cryptantha	T
False-yarrow	1
Hawksbeard, tapertip	1
Loco, specklepod	1
woollypod	T
Lupine	1
shortstem	T
Milkvetch, hangingpod	1
Mustard (yellow)	T
Pepperweed	T
Phlox (annual)	T
longleaf	T

Shrubs (max 20%)

Hopsage	T
Horsebrush, littleleaf	1
spiny	T
Rabbitbrush, threadlaef	1
Sagebrush, big	20

INFORMATION VALUES

Information of this nature is of value to resource managers because it identifies which ecological sites are valuable for management of wildlife such as sage grouse. It aids in communications between research and management but it fails in that it does not identify to habitat managers the conditions sought by the birds. It permits the application of research findings to other areas of similar capabilities only in a general way, that similar areas have similar potential. It does not identify the habitat conditions that must be duplicated to be successful habitat managers.

Within each of the existing ecological sites on these two different research areas there was variation in terms of shrub density, understory composition, and general range condition. Bird use was not evenly distributed throughout each site but related to existing conditions or plant communities. The site descriptions based on climax almost never described the habitats occupied by sage grouse.

For example, on the Sheldon National Wildlife Refuge the Ecological Site 690, Arid Loamy Terrace, tended to be in poor condition dominated by big sagebrush with little herbaceous or grass understory. In climax condition it never would contain many forbs, 5 percent ground cover maximum, but there could be 20 percent cover of Indian and Webber ricegrasses (Orozopsis hymenoides and O. webberi, respectively) and 20 percent bluebunch wheatgrass (Agropyron spicatum) (table 1). Cheatgrass brome (Bromus tectorum) and Sandberg bluegrass (Poa sandbergii) were the principal grasses at the time of the study and had greater abundance than given in the site description. Judging from the notable lack of understory this ecological site was much different than it would be if the range condition was improved.

The study of sage grouse indicated no value for sage grouse except in winter. This probably is a false conclusion relative to the potential for sage grouse because if the site were somewhat close to the potential as indicated in the site description, it probably would have value for nesting and brood rearing even though it was one of the more arid sites on the study area. Historically the 8-11 inches precipitation zone in Nevada produced sage grouse (Klebenow 1984-1985). Presently, the spring, summer, and fall grouse populations are nearly always found in zones above 10 inches precipitation.

Improving the condition of Ecological Site 690 (table 1), would supposedly lead to a decline in the amount of big sagebrush cover. If site potential was reached, 20 percent of big sagebrush cover should be adequate for all seasons including winter. Achievement of the climax vegetation potential on this site would reach its highest potential for year-long use by sage grouse.

OTHER TYPES OF SITES

But what of other sites? The climax potential is often not the best habitat management goal; consider ruffed grouse (Bonasa umbellus).

Gullion and Alm (1983) and Gullion (1984) in Minnesota have the habitat needs for ruffed grouse well defined. These grouse do best in quaking aspen (Populus tremuloides) dominated habitat, seral communities in coniferous forest. Within the aspen seral stage an interspersing of various aged aspen stands produces the most grouse.

Greater prairie chickens (Tympanuchus cupido) are another grouse that seek subclimax habitat, in this case burned tall grass prairie (Westemeier 1972). In forests, bobwhite quail (Colinus virginianus) also prefer subclimax habitat (Rosene 1969).

For the species where subclimax habitat is the goal of wildlife habitat management, ecological site descriptions do little other than identify the ecological name of these sites. It would be much more desirable if the habitat that exists could be categorized ecologically and that site descriptions would include descriptions of the site's seral stages. If that were achieved, then full communication would be possible between wildlife and land managers and ecological sites would be the common habitat management language.

WORKING TOWARD THE GOAL

Maybe the detail that I envision as desirable is more than we ever will achieve. I can see that the outlining of plant composition for all the seral stages of each ecological site would be a complicated task. Rating the wildlife potential for each stage will be another involved undertaking. Research would be necessary in a lot of cases to get a full understanding of the relationships between the successional stages of an ecological site and the reaction of wildlife. But I believe we should work toward this goal. It would allow for a more objective approach to wildlife habitat management for upland game birds and other wildlife than presently exists.

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SPECIAL CONSIDERATIONS WHEN CLASSIFYING RIPARIAN AREAS

Alma H. Winward and Wayne G. Padgett

ABSTRACT: Our ability to manage riparian areas will improve as we gain a better understanding of their ecology. Classification of these areas into community types and riparian complexes is helping to provide this understanding. Some ecological features unique to riparian settings are discussed.

INTRODUCTION

In our efforts to develop vegetation classifications for forest and rangeland settings, we somehow failed to adequately treat the riparian areas. In past classifications we either lumped riparian with upland types or, at best, divided riparian into the three broad categories of wet meadow, dry meadow, or browse shrub (USFS 1982). More recently, with the emphasis on better riparian management, there has been a major effort to refine classifications of these relatively small, but important, areas. Some of these efforts have centered around water or hydrologic characteristics (Rosgen 1985). Others have been based more on use oriented activities such as fish or wildlife habitat (Pfankuch 1978).

Current work by the Intermountain Region of the USDA Forest Service has emphasized a classification based on vegetation/site characteristics. The vegetation units are referenced as community types (CT's) and the site units as riparian complexes. Community types represent repeating stands (patches or islands) of similar vegetation with no reference made to successional status. Types are named after one or two dominant plant species in the community (Youngblood and others 1985a; Youngblood and others 1985b). Examples would be the narrowleaf cottonwood/Kentucky bluegrass (Populus angustifolia/Poa pratensis) CT or the tufted hairgrass (Deschampsia caespitosa) CT. Thus far, the classification includes a little over 100 CT's, about 80 percent of those we expect to find on National Forest lands in our Region.

The riparian complex represents a unit of land that supports or may potentially support a similar grouping of community types. It is

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identified on the basis of its overall geomorphology, and substrate, as well as its general vegetation pattern. It is named on the basis of the most common or prominent CT present, along with special features of the site on which it occurs. Examples would be the Alder/Dogwood-Steep Gradient-Narrow Valley Bottom Complex or the Tufted Hairgrass-Low Gradient-Wide Valley Bottom Complex.

The concept of the riparian complex is based on similar reasoning as that of the habitat type described by Daubenmire (1952). It is similar in that each, the habitat type and the riparian complex, represents units of land that have an inherent environmental potential to support certain kinds of vegetation. A major difference in the two is that the habitat type is based on a grouping of individual species (the association) while the riparian complex is based on a grouping of community types.

We are still in the early stages of identifying and naming riparian complexes. Thus far, these complexes appear to have high utility for serving as units for developing integrated management opportunities in the riparian setting.

SPECIAL FEATURES

As we began to look into the more detailed riparian classifications, we soon discovered special or unique problems and new challenges. One of the more perplexing difficulties encountered was the relatively small size and mosaic pattern of the CT's. Individual stands of a CT may range from a few square feet in size to several acres. Any one section of a stream or meadow is usually composed of numerous stands of several CT's. This became less of a problem as we eventually began to see and understand the pattern of these stands. Generally, one riparian complex has only four to eight CT's represented, with the distribution or pattern tied to the soils or, most often, water table features within that complex. The predictability of certain CT's to environmental settings soon helped us minimize the initial frustrations we had when we viewed them as an intermixed "scramble" of types. However, we did have to continue to think on a different scale (area basis) than we had been used to on surrounding upland types since one acre of riparian generally has several CT's present on it.

Another difficulty encountered in our classification efforts was the extent of disturbances these areas have received. Livestock, timber harvesting, recreational activities, and roads

potentially impact the vegetation and soil resources in these areas. Unlike the surrounding forest and rangeland types, most damaging influences are not limited to the area where they occur. Instead, many influences become cumulative down stream or lower in the watershed. This often makes it difficult to understand or to assign cause to particular disturbances.

"Natural" events also can cause detrimental impacts in the riparian setting. Fire, insect and disease outbreaks, and cyclic beaver activity tend to create everchanging environmental settings. Uncommon high run-off events can cause down-cutting of stream channels with subsequent heavy deposition elsewhere, and often, the relocation of stream channels. This feature alone can result in an almost continual readjustment of successional processes in some areas.

Because riparian ecosystems are often subjected to changes in the microenvironment, we have found the term "vegetation climax" (as used in the context of a self-perpetuating condition where species composition on a particular area becomes somewhat stabilized) is not always achieved, even under so-called "natural conditions." The exceptions include a few specially armored settings where bedrock or large cobbles/boulders keep the stream channel intact, or some low-gradient meadow situations that have stable enough settings for the vegetation to reach a balance with the environment.

In the remaining riparian areas there seems to be a continual breaking down or building up process that seldom allows the vegetation to have long-term stability. Lakes and ponds fill with sediments while river and stream channels move about in the valley floor with accompanying changes in nutrients and water table levels. Consequently, even under non-human influenced settings, the natural vegetation often represents only the mid-to late-seral stages, not the classical climax vegetation. Additionally, the probability is high that the seral stages will be relatively short lived. Major changes can occur in 10 to 20 years in riparian areas in contrast to successional process in surrounding upland vegetation where changes may require hundreds or even thousands of years.

This history of rapid change has produced some interesting riparian species adaptations. Many of the cottonwood, alder, birch, and willow species require, or at least regenerate much better, on disturbed or open ground. These species are very poor competitors in dense grass or heavily sodded settings (Winward 1986). Instead, they depend on newly developed sand and gravel bars, freshly broken banks, or seasonal deposition areas in order to regenerate and establish. Similarly, many grass and sedge species establish in new sections of a stream by anchoring chunks of sod broken from banks upstream. All these processes indicate a history of continual disturbances in riparian settings.

The continual disruption of succession in riparian areas does not necessarily prevent us from developing classifications based on potential of a site, nor does it leave us without an ability to use

vegetation communities--in our case the CT's, as descriptors of condition of an area. It means, instead, that we must realize we are generally working with communities that are not end-points in succession as we have tended to evaluate against on upland areas.

REALIGNMENT OF TYPES

We currently are evaluating a feature in riparian areas that is somewhat unique from processes on upland types. It appears that a common characteristic of the vegetation units within a riparian complex involves a swapping or realignment of stands of CT's. For example, a stand of one CT can establish and exist for several years in one specific location within the complex (fig. 1A, B). Then, as the environment supporting it is altered, such as a ground water change due to a changing of the stream channel (fig. 1C), that particular CT may reoccur somewhere else in the complex where the site features are now suitable (fig. 1D). Another type suited to the newly developed setting on the original area initiates development. Normally both types were present in that particular complex. Over time, stands of these two types have merely switched places. This realignment of stands of different CT's is unique from upland settings where stands of types may occur only on specific portions of a geographic area and those locations are essentially permanently set.

We are attempting to determine how much variability there is in composition of CT's in one complex, over time. In the process of interchanging locations within the complex, do the CT's remain in approximately the same relative composition even though individual stands move about in the complex? Also, is there enough commonality in CT composition in two geographic areas (the same complex in two different locations) that we can predict composition or composition potential from one geographic location to another? Our initial efforts suggest there is and that we can use this feature to help us understand and manage riparian areas. If there is a set kind and number of CT's within a complex in undisturbed conditions, and if new types enter the scene when unnatural disturbing factors, such as intense livestock grazing and trampling, or soil compaction from recreational activities, are present (fig. 1E), methods can be devised to quantitatively measure the degree of impact. For example, percent change in CT composition to CT's that indicate human-related activities can be used to measure degree of impact. In our riparian areas common new communities that come about as result of disturbances include: Kentucky bluegrass, willow/Kentucky bluegrass, red top (*Agrostis stolonifera*) or various thistle (*Cirsium*) species. The percentage of the composition of these types in a complex is an indicator of impact.

Complexes appear to be controlled by relatively stable factors such as stream gradient, valley bottom width, and elevation (geomorphology) or sometimes, by the size and pattern of water discharge, which is determined primarily by climate. Seldom do human-related influences change features of the overall geomorphology. Instead, human-caused influences normally involve changes in specific water

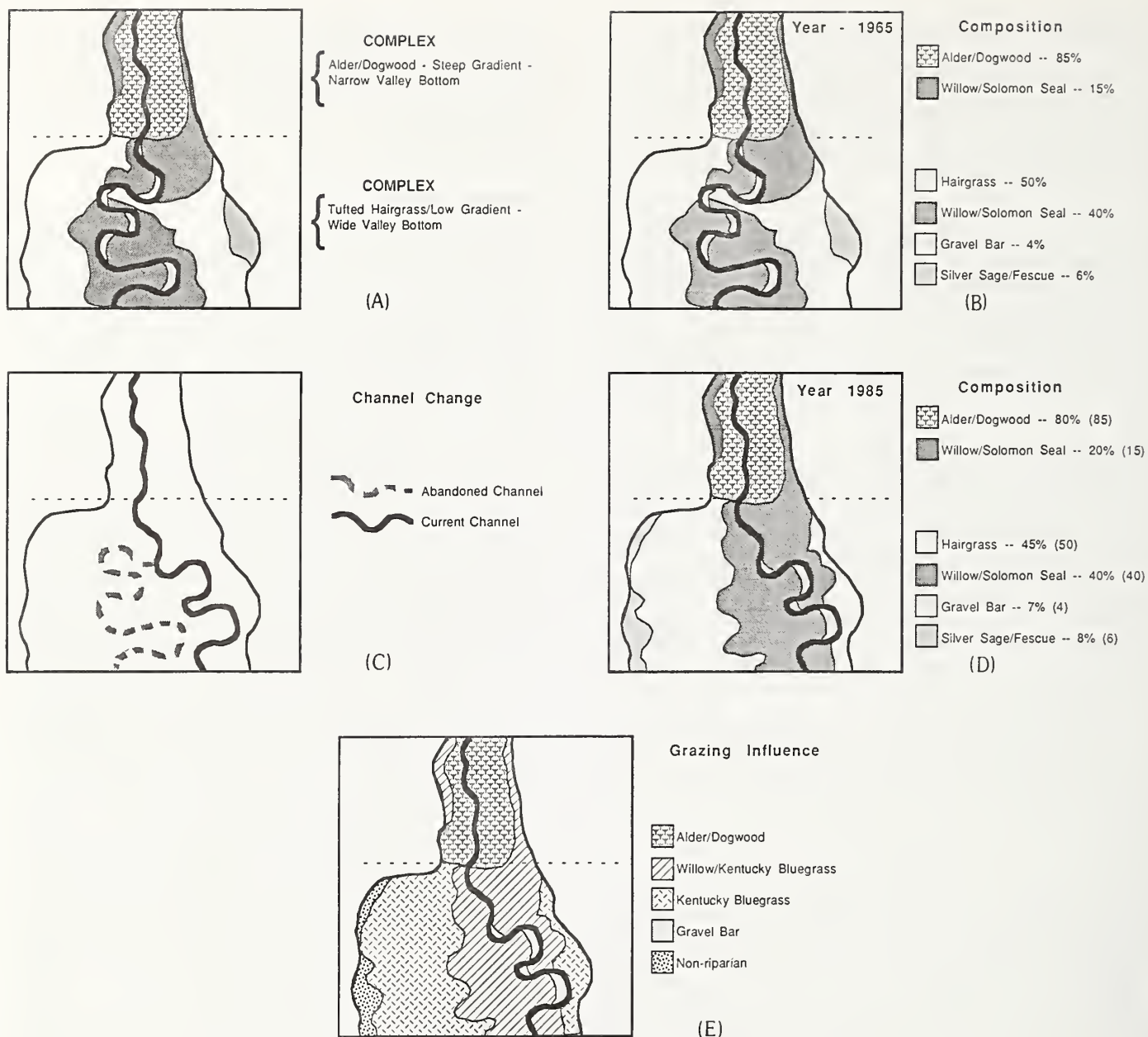


Figure 1--Graphical display of a typical riparian area in the Intermountain Region showing: (A) two riparian complexes along with stands of several community types within each complex; (B) community type composition in two riparian complexes during sampling period 1965; (C) a stream channel change that potentially may influence location of stands of the community types; (D) realignment of stands of each community type as a result of the channel change (sampling period 1985); and (E) common changes in kinds of community types in two complexes as a result of unnatural disturbance factors such as intensive grazing.

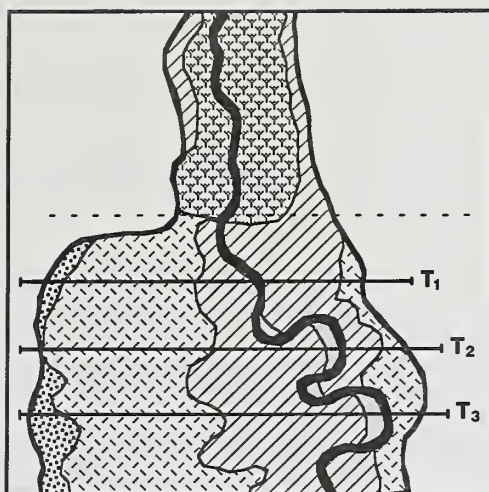
table or impact on certain plant species. These influences normally show up in changes in the CT composition within the complex.

We are developing sampling procedures that will help us monitor changes taking place in the riparian settings as a result of human-related activities. The line intercept method similar to that designed for use in obtaining individual species cover (Canfield 1941) is being tested as an approach for obtaining CT composition (fig. 2). Unmodified or minimally modified riparian settings are used to obtain representation of CT composi-

tion in least-altered status. These then may be used as standards to measure CT composition changes in settings with various stages of disturbance. Other common methods for measuring species density, cover, or frequency may also be used for more detailed evaluations (USDA 1986).

DISCUSSION

Development of riparian area classifications has been slow relative to upland classifications. This may have been related to their small size and



Grazing Influence

	T ₁	T ₂	T ₃	% Comp.
Alder/Dogwood				
Willow/Bluegrass	40	45	35	(40)
Kentucky Bluegrass	50	45	45	(47)
Gravel Bar		10	5	(5)
Non-riparian	10	T	15	(8)

Percent Disturbed = 87

Figure 2--Use of the line intercept method to measure amount of change in community type composition after unnatural disturbances.

complicated nature. Much effort is currently in progress to overcome this deficiency.

In the Intermountain Region of the Forest Service, we are finding that classification of these areas into riparian complexes (vegetation/site units) and into the further refined community types (vegetation units) has helped us gain a better understanding of the riparian setting. The complexes and/or community types serve as stratification units to help us understand features of the site, including the water, soil, and broad vegetational features. We are finding a definite relationship, for example, between the CT's and/or the complexes and the amount of natural bank breakage (Burton and others 1985; Winward 1986). Different CT's or complexes are also selected or preferred by livestock seasonally. Use of these types of classification units can help us answer questions about riparian area improvements. Questions such as: Which section of the stream should have willows? Which willow species should be used for rehabilitation? What species options do we have for understory establishment? Where and what type of in-stream structures would be appropriate? Similarly, knowledge of the tie between wildlife and fish to CT's or complexes can improve our efforts to provide better habitat. Finally, it should help us determine what type of research is needed to help us better manage these areas and, especially, where results of specific studies are applicable.

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UTILITY OF VEGETATION-BASED LAND CLASSES FOR PREDICTING FOREST REGENERATION AND GROWTH

Albert R. Stage

ABSTRACT: Habitat types representing potential vegetation are important indicators of forest productivity. Tree regeneration and growth rates can be estimated using habitat types such as those developed for northern Idaho. In the Stand Prognosis Model, most of the equations for regeneration and growth rates include habitat effects. For each species and equation, habitat types are combined into groups that respond similarly. However, the composition of the groups differs from species to species and from equation to equation so that, overall, each habitat type is unique. A land classification system based on habitat types is useful for growth and yield modeling, and hence in land management planning, if it meets the following criteria: (1) applies to all forest lands in the management unit; (2) is mappable into homogeneous units of 2 to 10 acres; (3) is unchanging with respect to stage of succession; and (4) evolves conservatively.

VEGETATION TYPES AS PRODUCTIVITY INDICATORS

One of the many expectations for vegetation-based land classification has been that the classes would indicate forest productivity. Evidence supporting this presumption has been available for quite some time. Etter (1949) in Switzerland described the relation of different site-types to productivity. In the northeastern U.S., Westveld (1951, 1952, 1954) proposed that climax forest type provided a sound basis for silvicultural prescription and for rating productivity, although his reports presented only a rank-ordering of sites by ground vegetation. Gagnon and MacArthur (1959) reported that ground vegetation could be used to indicate differences in diameter, height, and survival of white spruce plantations. And in Alberta, Canada, Corns and Pluth (1984) found that vegetational indicators added more accuracy to the prediction of growth than did soil and site properties.

In much of the United States, foresters have equated productivity with site index. Hodgkins (1961) reported the use of indicator plants to predict site index for longleaf pine (Pinus palustris), as did Roe (1967) for western larch (Larix occidentalis), and MacLean and Bolsinger (1973a) for ponderosa pine (Pinus ponderosa).

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Daubenmire (1961), however, showed that trends of ponderosa pine height growth with age differed markedly among habitat types, which were defined by potential climax communities. He demonstrated that the customary use of a single set of site-index curves for all sites in a region masked the relation of productivity to habitat types. Following his lead, Monserud (1984) produced a system of site index curves for Douglas-fir (Pseudotsuga menziesii var. glauca) in which curve shape varied among groups of habitat types that shared the same overstory union.

Habitat types also help explain differences in the relation of site index for one species to site index for an associated species in the same stand (Deitschman and Green 1965; Stanek 1966). These relations result from species differences in conditions for optimal growth.

Although it has been shown that there is substantial variation in site index between habitat types, it was also obvious that there is much variation in site index within a habitat type. Monserud (1984) working with inland Douglas-fir, for example, found standard deviations within habitat series of ± 10 to ± 14 feet of site index (base age 50 years) while the range among six series means was only 19 feet. For western white pine site index, some of the variation within a habitat type was found to depend on aspect and slope (Stage 1976).

The capacity of a site to support a vigorous stand at a particular density has been recognized as a component of forest productivity that is not always related to the height growth potential represented by site index (MacLean and Bolsinger 1973b). Hall (1983), in his definition of "growth basal area," provided an objective index of carrying capacity. His index expresses the basal area at which dominant, 100-year-old trees will grow 1 inch in radius per decade. His measure is closely related to the self-calibration procedure used by Stage (1981) to compare diameter increments at a given stocking level. Both procedures were designed to quantify differences in productivity between stands having the same height growth potential. Hall showed that his growth basal area index varied among community types. Similarly, Pfister and others (1977) found differences in basal area carrying capacity among habitat types in Montana.

RELATIONS OF HABITAT TYPES TO STAND DYNAMICS

Habitat types have much more profound relations to growth and yield, and hence to productivity, than is represented by site index variation. The Stand

Prognosis Model (Stage 1973; Wykoff and others 1982) will be used to illustrate these effects, because the Inland Empire variant of this model is the only generally used yield forecasting system in which habitat types in concert with physical site factors but not site index indicate differing growing conditions. Not all variants of the Stand Prognosis Model use habitat types, because data available to calibrate the model for many regions did not include habitat type, but did include site index.

Habitat types play a key role in all three major components of the model:

- Regeneration (Ferguson and others 1986)
- Accretion (Hatch 1980; Stage 1975; Wykoff 1983, 1986; Wykoff and others 1982)
- Mortality (Hamilton 1986; Hamilton in preparation)

Regeneration

In the regeneration component, habitat types are significant predictors of (1) probability of stocking, (2) numbers of seedlings given that the plot is stocked, (3) species presence in the regeneration, and (4) height growth of newly established seedlings.

Accretion

Any model of accretion rates requires some measure of site quality or its separate factors such as growing season length and heat, moisture, and nutrient availability. Whereas site quality is essentially a continuous variable, or a set of continuous variables, land classes have discrete boundaries, at least in concept. Therefore, one would a priori expect a continuous variable such as site index to be a more effective representation of site quality than variables defined by discrete classes such as habitat types.

Of the elements of the accretion component, diameter increment was the first in which habitat types were tested as an alternative to site index. The diameter increment model introduces habitat type in two roles. Because the model has a logarithmic dependent variable, the intercept terms, which depend on habitat types, multiply the rates represented by the other terms. In addition, the coefficients of stand density differ by habitat type, representing differences in carrying capacity of the site. Wykoff's (1983) analyses showed that some habitat types could be combined into groups that did not differ significantly, but that the groupings differed for each of the 11 tree species in his data. Of 28 habitat types, only two pairs were combined in the same way for all species--and these were types for which there were few data. Here, as for height growth, species are responding differently to the factors being represented by habitat types. Ten-year diameter increment predicted by this model is shown for differing habitat types within the St. Joe National Forest in table 1. These values are computed for a dominant Douglas-fir of 10-inch d.b.h., growing on flat ground in a stand having 60 percent of the basal area carrying capacity for the type.

Although there is a range of 0.6 inches in these estimates, the range among National Forests within just the Abies grandis/Clintonia uniflora habitat type (table 2) is equally large.

Table 1--Ten-year diameter increments predicted by the Prognosis Model for dominant Douglas-fir of 10-inch d.b.h. growing at the indicated densities on flat ground in the St. Joe National Forest, ID

Habitat type	Density (60% of carrying capacity)	10-yr diameter increment (inside bark)
	ft ²	Inches
<u>Pseudotsuga menziesii</u> / <u>Physocarpus malvaceus</u>	202	1.39
<u>Abies grandis</u> / <u>Clintonia uniflora</u>	247	1.39
<u>Thuja plicata</u> / <u>Clintonia uniflora</u>	286	1.59
<u>Tsuga heterophylla</u> / <u>Clintonia uniflora</u>	254	1.50
<u>Abies lasiocarpa</u> / <u>Clintonia uniflora</u>	286	1.44
<u>Tsuga mertensiana</u> / <u>Xerophyllum tenax</u>	169	1.21
<u>Abies lasiocarpa</u> / <u>Xerophyllum tenax</u>	254	1.19
<u>Abies lasiocarpa</u> / <u>Menziesia ferruginea</u>	260	1.12
<u>Tsuga mertensiana</u> / <u>Menziesia ferruginea</u>	228	0.99

Table 2--Ten-year diameter increments predicted by the Prognosis Model for dominant Douglas-fir of 10-inch d.b.h. growing on flat ground in the Abies grandis/Clintonia uniflora habitat type at a density of 247 ft² of basal area by National Forest location

National Forest	10-yr diameter increment (inside bark)
	Inches
Nezperce	1.23
Clearwater	1.28
St. Joe	1.39
Coeur d'Alene	1.11
Kaniksu	1.10
Bitterroot	0.70
Lolo	0.78
Kootenai	0.96
Flathead	0.97
Colville	0.98

Two studies have tested the sufficiency of habitat types for representing site quality in diameter growth models. For six species represented in 102 permanent growth plots in the Abies grandis/Pachistima myrsinites, the Tsuga heterophylla/Pachistima, and the Thuja plicata/Pachistima habitat types, I found that these three habitat types accounted for as much or more variation as did reliable estimates of site index.

A further, rather rigorous, test of the adequacy of habitat types (used in conjunction with slope, aspect, elevation, and geographic location) was conducted by Wykoff and Monserud (1987) for Douglas-fir. Again, use of site index did not improve the accuracy of the predictions.

Height increment has, from the inception of the Stand Prognosis Model, relied on habitat type (Stage 1975). The original model for trees greater than 5 inches d.b.h. was based on an allometric relation between height and diameter. In this model, habitat type affects both the allometric constant describing bole taper, and the constant setting the overall growth rate. However, as experience with the model accumulated, we saw that further improvement would come from adding a habitat type effect modifying the curve shape. The effect of this change was to reduce the height increment of tall trees on the warm-dry sites more than on the cold-moist sites (Wykoff and others 1982).

The submodel for height growth of trees less than 5 inches d.b.h. also relies on habitat type. Habitat types are grouped into as many as six classes according to similarity in submodel coefficients. The makeup of the classes also differs for each species.

Mortality

Mortality is strongly related to tree vigor, which in turn, is related to rates of increment. Therefore, all the factors that influence increment also influence mortality. Habitat types have been cited as a major factor in the accretion component of the Stand Prognosis Model, so it is no surprise that they also influence mortality. However, the actual data used to calibrate the model came from a limited range of habitat types (Hamilton 1986), which are among the most productive in the Inland Empire. Hence, the problem is to extrapolate in a reasonable way, based on theory, to other habitats which are less productive. The details of the procedure described by Hamilton (in preparation) rely on estimates of potential diameter growth rates and carrying capacity. Both of these variables depend on habitat types--the former through the diameter increment model described previously (tables 1 and 2), and the latter on estimates of basal area carrying capacity contained in the documentation of sample plots used in developing the classification of habitat types (Pfister and others 1977).

Net Productivity

Effects of habitat types on the components of the Stand Prognosis Model are so intertwined that

demonstration of net effects on productivity is difficult to illustrate. Habitat types do not occur independently of the other factors of the site such as elevation, slope, aspect, and physiographic and geographic location. Therefore, illustrations prepared by holding all other factors constant and varying only habitat type will understate differences in productivity. However, by simulating plantations having different survival rates, the understatement can be reduced. Figure 1 shows simulated development of total cubic foot production and top-height for Douglas-fir planted at 500 trees per acre. Five-year survival is postulated at 90 percent on the Tsuga and Abies grandis habitats and 70 percent on the Pseudotsuga and Abies lasiocarpa habitats.

Validation of Effects

Comparison of actual growth records with simulations of expected growth is the final test of how well habitat types serve, in concert with other physical site factors, as a basis for yield forecasting. Because the Stand Prognosis Model does not use site index, bias in estimating heights of the 40 trees of largest diameter in the stand might vary with site index. Figure 2, based on 102 remeasured plots with an average duration of 39 years, shows that the estimates are not correlated with site index. Likewise, deviations in basal area are not correlated ($r = -0.049$) with site index.

REQUIREMENTS OF LAND CLASSIFICATIONS FOR GROWTH MODELING

Experience with using the habitat type classification in the Stand Prognosis Model, and in turn, using the estimates for land management planning suggests four criteria to be met.

1. Complete classification of all lands in a planning unit such as a National Forest should be feasible. This requirement implies that classification should be possible, using objectively definable criteria, by inventory crews given reasonable training.

2. Units should be mappable at resolutions of 2 to 10 acres per unit. In rough terrain, larger minimum sizes might imply inclusions of habitats having very different growth characteristics. Accommodating variation within units substantially increases the complexity of the growth and yield estimation system to be applied.

3. Classification should not change with stage of succession. In other words, seral classes would only be useful if they are seral to a single class of potential vegetation. This requirement avoids the indeterminacy that would result if a class assigned to the stand at time of inventory could evolve into two or more climax classes that might differ in their growth coefficients.

4. New systems of classification should evolve conservatively from their predecessors. To develop a growth and yield model based upon a

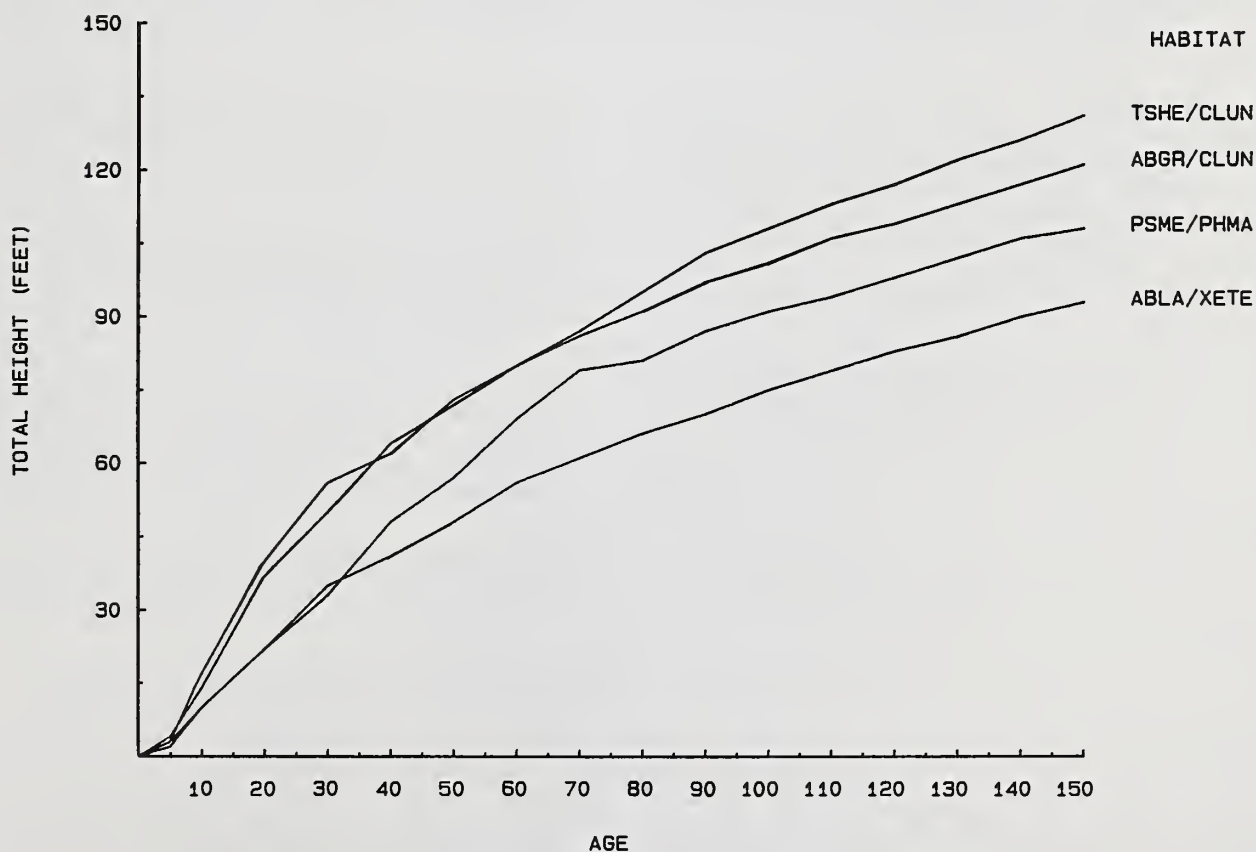
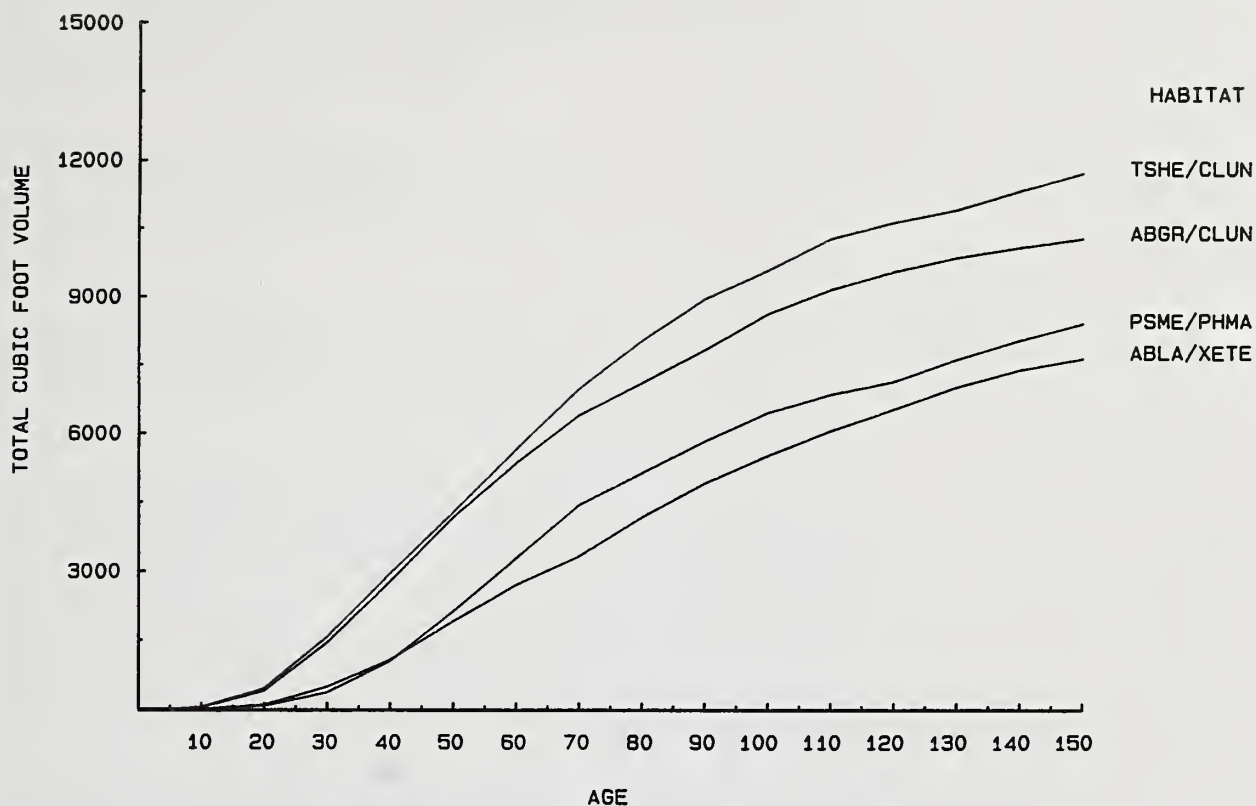


Figure 1--Predicted development of total cubic-foot volume and top height for four habitat types planted with 500 Douglas-fir trees per acre.

PERMANENT SAMPLE PLOT RESIDUAL ANALYSIS

NOCALIB ACTUAL MORTALITY
HEIGHT BIAS VS. SITE INDEX

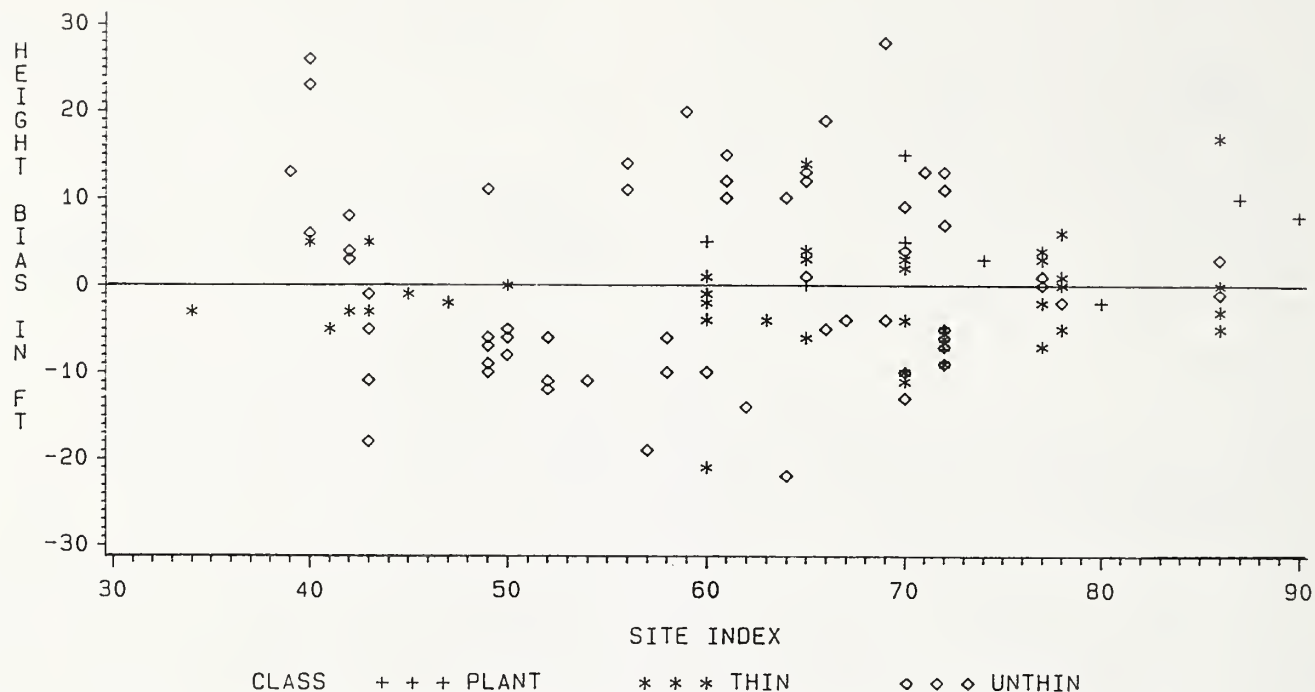


Figure 2--Differences between model predictions and observed values of stand top height (40 largest d.b.h./acre) versus site index, based on 102 plots in the *Abies grandis*-*Tsuga heterophylla*-*Thuja plicata* series. Vertical axis is observed values minus model predictions.

particular classification system requires time and substantial investment. In turn, application of the model requires that inventory data be classified to the same standards used in calibrating the growth relations. Hence, it is important that refinements be built upon the existing classification by dividing existing classes. In this way, the relations developed with the former system can be used while new data are accumulated for the revised system.

If these criteria are met, land classification based on vegetation provides a useful ecological foundation for estimating the dynamics of stand establishment, growth, and response to management.

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INFLUENCE OF HABITAT TYPES ON FOREST PESTS OF THE NORTHERN ROCKY MOUNTAINS

Clinton E. Carlson

ABSTRACT: Major pests of Northern Rocky Mountain forests are affected by environmental conditions and vegetation depicted by habitat types (h.t.), but the interactions are weakly understood. Mountain pine beetle activity is limited in high-elevation PICO and ABLA h.t.'s where weather is very cold and moist, but is high in midelevation ABLA and PSME types where weather is more moderate. Western spruce budworm is most active on dry, warm PSME and ABGR h.t.'s, and similar to the beetle, is least active in the cold, wet ABLA types. *Armillaria* spp. occur most frequently in the productive ABGR, THPL, and TSHE h.t.'s but cause most damage in the poorer PSME and ABGR types. Susceptibility (probability of occurrence) and vulnerability (probability of damage) to all three pests seem to depend on relative shade tolerance of the host species. In general, when more than one host species is present, the most shade-tolerant ones, or the indicated climax, will be most susceptible and vulnerable to the pest. But when only one host species is present, and it is seral--such as lodgepole pine on ABLA h.t.s'--it may be extensively exploited by the pest. Multiple-use values are usually enhanced when forest management is structured to favor the seral species.

INTRODUCTION

Classification of forest sites using the habitat type system is well accepted and used extensively throughout much of the Western United States. This ecologically based system gives users a common basis from which to discuss proposed management activities affecting forest resources (Pfister and Arno 1980). Habitat types differ in climate, soils, and topography. These basic site differences, combined with disturbances such as fire, significantly influence succession and seral plant communities (Arno and others 1985). Forest pest activity is dependent on presence of a susceptible food base and favorable environmental conditions. Successional stage of the plant community, climate, and weather influence substrate susceptibility, ultimately affecting

the pest. Knowing how the ecological factors associated with habitat types interact with forest insects and diseases would help land managers deal with these pests. The purpose of this paper is to synthesize current information concerning relations between habitat type and three major forest pests of the Northern Rocky Mountains--western spruce budworm (*Choristoneura occidentalis* Freeman), mountain pine beetle (*Dendroctonus ponderosae* Hopk.), and *Armillaria* spp. root disease. In this paper, influence of habitat type on pests means the combined influence of underlying environmental factors associated with habitat type.

MOUNTAIN PINE BEETLE

Mountain pine beetle is found throughout the range of its primary host, lodgepole pine (*Pinus contorta* ssp. *latifolia*). The range includes many habitat types. From an ecological perspective, it is meaningful to consider the habitats where lodgepole occurs to understand the wide amplitude of the beetle. According to Pfister and Cole (1985), lodgepole is minor seral in 10 habitat types, dominant seral in 26, and persistent/climax in 6 (table 1). Abbreviations of habitat type names follow Pfister and others (1977).

On warm, dry habitat types, where lodgepole is minor seral, average annual precipitation is about 18 inches and mean July temperature is about 62 °F. Where the species attains its greatest importance (dominant seral), and where mountain pine beetle is a significant problem, precipitation averages around 40 inches annually and mean July temperature is about 60 °F (Pfister and others 1977). Clearly, lodgepole pine and the beetle have broad ecological amplitudes in the Northern Rockies. But the beetle is subjected to a narrower range of specific conditions because the tree acts as a buffer between the insect and the outside environment.

Although the ecological amplitude of the beetle is known, the specific influence of habitat type on the insect has received little attention and is not well understood. Evidence is conflicting and difficult to interpret. Roe and Amman (1970) reported that current beetle activity, measured by the number of stands infested, was highest in ABLA/PAMY habitat types in northwestern Wyoming and southeastern Idaho--92 percent of the stands observed were infested. Activity was intermediate in PSME/CARU types--64 percent--and lowest in ABLA/VASC types where only 44 percent of the

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Table 1--Ecological role of lodgepole pine in the Northern Rocky Mountains (modified from Pfister and Cole 1985)

	Habitat type			
Successional role	Warm, dry	>>>>>>>>>>>>>>>>>>>>		Cold, moist
Minor seral	PSME/SYAL	ABGR/CLUN		ABLA/LUHI
	PSME/PHMA	ABGR/LIBO		TSME/MEFE
	ABLA/CLPS	TSHE/CLUN		TSME/LUHI
		THPL/CLUN		
Dominant seral	PSME/LIBO	PICEA/PHMA	ABGR/ZETE	ABLA/CAGE
	PSME/CARU	ABLA/CLUN	PSME/VAGL	ABLA/PIAL/VASC
	ABLA/CARU	PSME/VACA	ABLA/XETE	ABLA/CACA
		PICEA/CLUN	PSME/JUCO	ABLA/VASC
		PICEA/GATR		ABLA/MEFE
		PICEA/LIBO		TSME/XETE
		PICEA/SMST		
		PICEA/VACA		
		ABLA/VAGL		
		ABLA/ALSI		
		ABLA/ARCO		
		ABLA/GATR		
		ABLA/LIBO		
Persistent/climax		PICO/VACA	ABLA/VACA	
		PICO/LIBO	PICO/PUTR	
		PICO/CARU		
		PICO/VASC		

stands were infested. But infestation intensity was about the same among habitat types. In a study conducted on the Gallatin National Forest (NF) in Montana, beetle activity was measured as percent lodgepole mortality expressed in basal area/acre, in trees greater than or equal to 8 inches d.b.h. (McGregor 1978). In that study, McGregor purported to show an effect of habitat type on beetle activity. On a relatively dry elevational gradient, most activity was found in the PSME/CARU-CARU and ABLA/CARU habitat types (42 percent mortality in each type). Slightly lower mortality (40 percent) was observed in the ABLA/ VASC-CARU type, and least activity (25 percent) was noted in the ABLA/VASC-VASC type. On a moist gradient, most beetle-caused mortality was found in the PICEA/LIBO type and least in the ABLA/ALSI type (table 2).

McGregor's (1978) analysis was confounded by changing basal area of lodgepole and elevation of the stands. Thus, the effect of habitat type on the beetle is not predictable based on that work. One can only state that in those stands at that time, mortality due to the beetle was at the observed levels.

Analyses of more recent data from the Gallatin NF indicated that habitat type was associated with percentage of trees killed and cubic volume lost due to beetle activity (Cole and McGregor 1983; Cole and others 1985). Bivariate models were constructed, using percentage of trees killed as the dependent variable and time (years) as the independent variable. Models were computed on a stand-by-stand basis where each stand had a unique habitat type. Models for several stands were plotted on each graph, and the differences

Table 2--Mountain pine beetle-caused tree
mortality, habitat type, lodgepole pine
basal area, and elevation on the Gallatin
NF (from McGregor 1978)

Habitat type	Slope environment	LPP basal area in stand (%)	Elevation (Ft)	Mortality (%)
PSME/CARU	Dry	48	6,000	42
ABLA/CARU	Dry	61	--	42
ABLA/VASC-CARU	Dry	81	--	40
ABLA/VASC-VASC	Dry	83	8,000	25
PICEA/LIBO	Moist	25	5,800	40
ABLA/LIBO	Moist	61	--	40
ABLA/VAGL	Moist	71	--	20
ABLA/ALSI	Moist	58	8,000	13

between models were attributed to habitat type. The plotted regression lines (Cole and McGregor 1983), however, did not match the models presented. The models were developed with mortality data from only 2 years--the first and last--10 years hence. Yet the time axis (X) on the graphs of the regression models included 11 years. Gayle Yamasaki, who did the original analyses, clarified the problem. If the quantity $(1 + X/10)$ is substituted for X in the models, the models match the plotted equations (Yamasaki 1988). One further correction in the graphs--the ordinates should be labeled "proportion of trees lost to

beetles" instead of "percent of trees lost to beetles." Because only two points were used in calculation of the regression models, it is difficult to know whether the relations are linear or curvilinear.

It also is difficult to recognize an effect of habitat type on beetle activity based on the Cole and McGregor (1983) models. The models were very dissimilar for a given habitat type from two different (but geographically close) areas. The model for ABLA/CARU at Hebgen was $Y = 0.113 + 0.044X$, whereas the ABLA/CARU at Madison was $-0.185 + 0.209X$ (Cole and McGregor 1983). The slopes and intercepts are very different and there appears to be as much variation within h.t.'s as between. This is not surprising--the effects of slope, aspect, elevation, soils, tree size, and stand age were not considered in the analyses. No statistics, such as the coefficient of determination, error mean square, confidence intervals, or analyses of variance, were given so it is impossible for the reader to evaluate goodness of fit for any of their models. Each model represents a case history for each stand sampled. Differences between stands may or may not be due to habitat type. Perhaps a reanalysis of their data, using multivariate or multiple regression techniques, would be enlightening.

Future studies of relations between mountain pine beetle and its environment should, as Cole (1985) aptly suggested, be couched in an ecological framework. All variables suspected of influencing the insect should be measured at each sampling point. These include, but are not limited to, soils, slope, aspect, elevation, habitat type, successional stage, amount of host and non-host, host size, age, vigor, stand density, and recent weather.

Seral status of host species may also be important in beetle dynamics. Mountain pine beetle caused extensive mortality in pure ponderosa pine (*Pinus ponderosa* ssp. *ponderosa* Dougl.) stands about 8 to 10 inches d.b.h. on ponderosa pine habitat types south of Bend, OR. In nearby lodgepole pine habitat types, however, where ponderosa was seral and mixed with climax lodgepole, the lodgepole was heavily damaged by the beetle, yet the ponderosa was seldom affected (Carlson 1987). Where both species are seral, mortality has been about equal between them (Gibson 1987). Multivariate analyses may elucidate pertinent relations between beetle activity and these variables. At present, however, little definitive work has been accomplished concerning the influence of habitat type on mountain pine beetle. This statement is supported in that current models simulating beetle dynamics do not use habitat type as a predictor variable (Raffa and Berryman 1986; Schenk and others 1980).

WESTERN SPRUCE BUDWORM

Like mountain pine beetle, western spruce budworm has a broad ecological amplitude in the Northern Rockies (table 3). Budworm occurs in many habitat types in six forest climax series ranging from

Table 3--Occurrence of western spruce budworm in Montana by forest climax series (from Carlson and others 1985)

Forest climax series	Elevational range (Ft)	Mean annual precipitation (In.)	Mean July temperature (°F)
PSME	2,000-7,800	17-20	60-66
PICEA	2,900-8,600	23-26	56-61
ABGR THPL TSHE	2,000-5,000	30-34	64
ABLA (lower sub-alpine)	3,200-8,500	21-53	57-64

the warm, dry PSME to the cool, moist ABLA. The insect is found from elevations as low as 2,000 feet MSL (mean sea level) to higher than 8,500 feet, and occurs on all slopes and aspects.

Budworm is seldom found in the upper ABLA habitat types where the weather is too cold and wet. In other habitat types, stand susceptibility to the insect varies with several factors, including regional climate, intrinsic site climate, species composition, host/nonhost density, stand structure, stand vigor, stand maturity, and continuity of surrounding host type (Carlson and others 1985). Intrinsic site climate (the integration of slope, aspect, elevation, and general climate) was indexed by habitat type in rating stand susceptibility to budworm (Wulf and Carlson 1985) as shown in table 4. The index reflects the knowledge that warm, dry habitats are most favorable for budworm (Wulf and Cates 1987).

Table 4--Relative importance of habitat type in stand susceptibility to budworm (from Wulf and Carlson 1985)

Habitat group	Index value
Cold ABLA, timberline types	0
Cool, moist PICEA; cool, moist ABLA types	0.6
Warm, moist ABGR; THPL, TSHE; warm, moist ABLA types	1.0
Cold PSME; cold ABGR; cool, dry PICEA; cool, dry ABLA types	1.2
Moist ABGR; warm, moist PICEA; warm, moist ABLA types	1.3
Mesic PSME; dry ABGR; warm mesic PICEA; warm, dry ABLA types	1.4
Warm, dry PSME types	1.5

Budworm feeding activity varies significantly with habitat type (Carlson and others 1982). Regression analyses relating budworm-induced radial growth depression to elevation, proportion host basal area, slope, aspect, and habitat type suggested that growth reduction was highest on south-facing steep aspects in dry PSME and ABGR habitat types. The influence of budworm on natural regeneration following harvest also is dependent on habitat type. On dry south-facing PSME habitats where slope was 40 percent, stocking probability was only 0.12 (fig. 1). But on moist ABLA habitats with slopes of 60 percent, where defoliation of the host species was similar to that observed on the PSME types, stocking probability was about 0.60 (Carlson and others 1982). Poor regeneration on the PSME habitats was attributed to seed and cone depredation by budworm, fewer conifer species, and generally poorer environmental conditions for seedling germination and establishment. Finally, the influence of habitat type on budworm is strongly dependent on host presence and abundance. A ponderosa pine/western larch (Larix occidentalis Nutt.) seral community on a PSME habitat type obviously would not be susceptible to budworm, unlike a Douglas-fir sere. Even though larch is vulnerable to budworm (may be damaged), the species is not very susceptible (will not support the life cycle).

Host susceptibility is strongly influenced by habitat type. For example, Douglas-fir on a PSME habitat type is highly vulnerable to budworm. But when in a seral role, Douglas-fir is far less preferred by the insect. On ABGR and ABLA h.t.'s in central Idaho, grand fir (Abies grandis

(Dougl.) Forbes) and subalpine fir (A. lasiocarpa (Hook.) Nutt.) were heavily defoliated; Douglas-fir was barely affected (fig. 2) (Carlson and others 1985; Wulf and Cates 1987). In reviewing aerial survey maps of defoliation and correlating them with forest cover type and habitat type, Sutherland (1983) noted that Douglas-fir was much less defoliated on ABGR and ABLA fir habitat types than where it was climax. In northeastern Oregon, where budworm was epidemic for 8 to 12 years, radial growth of Douglas-fir was less severely affected than that of grand fir or Engelmann spruce (Picea engelmannii Parry) on, presumably, grand fir habitat types (Williams 1966). Reasons for this changing susceptibility are unknown. Sutherland (1983) postulated that Douglas-fir in a seral role may be more vigorous and more able to resist insect attack. Another hypothesis is that volatile foliar compounds influence feeding preference. Small second-instar budworms are evenly dispersed in spring (Carlson and others in press). After being wind-dispersed the tiny larvae search for suitable feeding sites. The search may be chemically mediated--the larvae "sniff" for suitable food. If grand fir and subalpine fir, which are highly aromatic, release better or more appropriate chemical stimuli than Douglas-fir, the small larvae would tend to leave the Douglas-fir and would probably die. Larvae on the true firs likely would stay there, resulting in differential defoliation. In pure Douglas-fir stands, however, this hypothesized chemical gradient would not be present, and larvae would tend to stay put, resulting in more even defoliation. These are only hypotheses; mechanisms for the differential susceptibility of Douglas-fir to budworm among habitat types remain unknown.

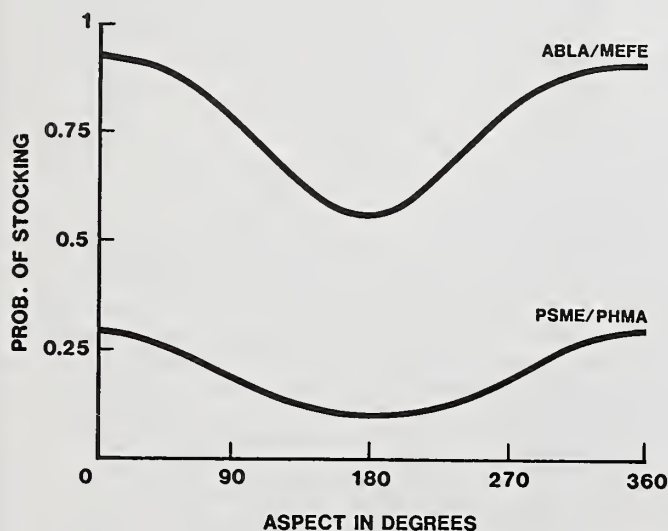


Figure 1--Influence of habitat type and aspect on probability of stocking in the Northern Rocky Mountains. Western spruce budworm contributed significantly to the low stocking in the PSME/PHMA h.t.'s.



Figure 2--Effect of seral status of host species on vulnerability to budworm. On this ABGR h.t., grand firs, the climax species for the site, are extensively damaged by the insect; Douglas-firs, which are seral, are not affected.

ARMILLARIA ROOT DISEASE

Armillaria spp. are ubiquitous, causing root disease in forbs, shrubs, and broadleaf and conifer trees across a wide range of environments. It is a serious disease. James and others (1984) identified root disease centers on nearly 78,000 acres (1 percent of the total forested area), in seven Northern Rocky Mountain National Forests. Taxonomy of Armillaria spp. is in question. Armillaria mellea (Vahl. ex Fr.) Kummer was generally recognized as the causal organism until recently when other Armillaria species were suspected of causing disease (Wargo and Shaw 1985). In the Northern Rockies, plant pathologists hypothesize that the fungus, perhaps A. ostoyae, may function as a facultative pathogen, causing disease in trees already under stress (McDonald and others 1987a). Whatever the case, Armillaria is likely present in every habitat type of the Northern Rockies.

Habitat type apparently influences root disease. Williams and Marsden (1982) discovered that stands older than 100 years and stocked primarily with Douglas-fir and grand fir were more likely to have root disease centers (Armillaria and Poria weirii) when on PSME and ABGR habitat types than when on TSHE types (fig. 3). Other site and stand factors related to habitat type had a major influence on disease. Probability of disease increased with increasing age (up to 100 years), was highest on east to southeast aspects, and interacted with soils and aspect (Williams and Marsden 1982).

Recent work corroborates and extends the work of Williams and Marsden (1982). McDonald and others (1987a) randomly sampled 78 plots in the Northern Rocky Mountains and determined the incidence of pathogenic Armillaria. Proportion of plots with

pathogenic Armillaria on conifer species decreased as habitat productivity increased. TSHE h.t.'s had the least amount of disease, followed by THPL, ABGR, PSME, and ABLA in increasing order of incidence. Disturbed plots on the highly productive types had more disease than undisturbed; the opposite was true for the least productive types. Furthermore, Douglas-fir, grand fir, sub-alpine fir, and Engelmann spruce were most susceptible when they were climax, not seral.

Assessing the general distribution of Armillaria, not just its pathogenic occurrence, resulted in different conclusions (McDonald and others 1987b). TSHE and THPL h.t.'s had the highest proportion of plots with the fungus, 0.93 and 1.00 respectively, but the least amount was found on the ABLA (0.42) and PSME (0.33) h.t.'s (table 5). In the general distribution, incidence of Armillaria was assessed on hardwoods and conifers on each plot. Pathogenic occurrence was assessed only on conifers. Thus, even though the fungus can be found just about anywhere in the forest, and in greatest frequency on good sites, expression of the disease is probably regulated by specific site and stand factors. Nutrient and moisture stress, likely affected in large part by habitat type, are hypotheses to be tested.

Table 5--Probability of general and pathogenic occurrence of Armillaria in the Northern Rocky Mountains (from McDonald and others 1987a and 1987b)

Habitat series	Probability of general occurrence	Probability of pathogenic occurrence
ABLA	0.42	0.53
PSME	.33	.67
ABGR	.79	.31
THPL	1.00	.20
TSHE	.93	.13

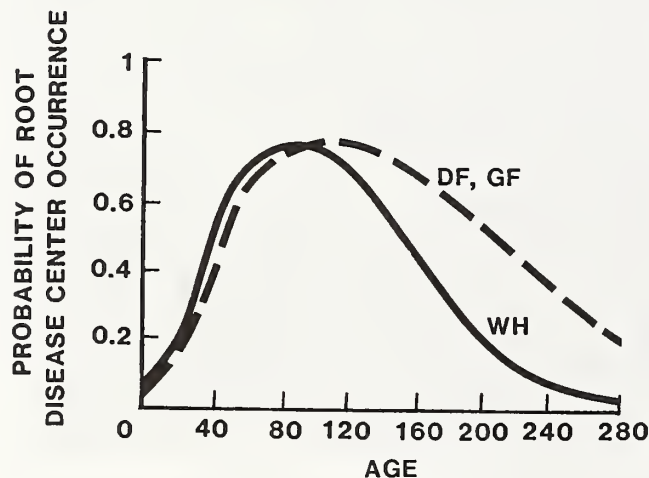


Figure 3--Influence of habitat type and stand age on root disease center occurrence. DF, GF, and WH mean PSME, ABGR, and TSHE h.t.'s, respectively (from Williams and Marsden 1982).

CONCLUSIONS

The influence of habitat type on forest pests, including mountain pine beetle, western spruce budworm, and Armillaria root disease, is not well understood, but we are beginning to see some relationships. Mountain pine beetle incidence seems not to be closely related to habitat type--other factors, such as elevation, slope, and aspect, seem to be more influential. Much of the work on the beetle has been done during epidemics, and the population momentum probably overrides many environmental influences. Study of endemic populations may reveal some of the more intricate relationships between the beetle and its environment. Budworm is active over a wide range of environmental conditions, but warm, dry PSME h.t.'s seem to be most favorable to this insect. Armillaria root disease also appears most damaging in drier habitats.

A common host-pest interaction may be hypothesized for all three pests discussed. When more than one host species is present, the pest is most active on the most shade-tolerant or the climax host. On ABGR and ABLA habitat types, budworm causes far more damage on grand fir and subalpine fir than on Douglas-fir. But on PSME h.t.'s, Douglas-fir is extensively defoliated. Similarly, on a given h.t., Armillaria root disease and mountain pine beetle apparently are most active on the climax species. This hypothesis needs to be tested. If it turns out to be true, then managing intensively for seral species should reduce pest activity over the long run.

Studies on the effect of habitat type on forest pests need to consider successional stage. Methods to classify successional stages are under development and will add a new and very important stabilizing variable to forest pest research (Arno and others 1985; Steele 1984). Studies designed to include successional stage, slope, elevation, aspect, and soils data within habitat types are needed to explain the high amount of variability observed to date. Once we have this level of knowledge, Vasechko's (1983) concepts on forest protection through ecological approaches may have a chance to succeed.

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SOIL-HABITAT TYPE RELATIONSHIPS:

A THEORETICAL MODEL

Kenneth E. Neiman, Jr. and Minoru Hironaka

ABSTRACT: Studies of site factors have led to theories that both soil development and plant community composition are functions of climate, parent material, relief, and potential organisms interacting over time. This paper presents a theoretical model based on the premise that one habitat type can be correlated with many soils, but an individual soil is only related to a single habitat type. This model creates a means by which similar seral communities can be assigned to their proper habitat type and more accurately positioned within successional development pathways.

INTRODUCTION

Vegetation-based land classification systems (such as Daubenmire and Daubenmire 1968; Pfister and others 1977; Hironaka and others 1983; Johnson and Simon 1987; and others) depend on knowledge of existing floristics for identification of taxonomic plant associations. On forested lands that have not been severely disturbed, habitat type identification can be accomplished with relative ease. But as more land is subjected to the severe disturbances of even-aged management prescriptions, future habitat type identification will require extrapolation from highly disturbed seral plant communities which often have little floristic similarity to the climax community. As severe disturbances increase so does the need to extrapolate habitat type identification from seral community types by using both biotic and abiotic site characteristics.

Hypothetically, all sites with similar vegetation, climate, site characteristics, parent material, and age should have soils with similar horizonations and chemical compositions (Jenny 1941). Due to environmental factor compensation and physiological plasticity of species, we find many sites that have similar vegetation composition, although these sites do not have similar physical environments. Consequently, we find the same climax plant association occurring on both north and south aspects or

over highly different parent materials. Thus, different soils often develop beneath similar vegetation communities.

This paper expands on a conceptual model of secondary succession developed by Huschle and Hironaka (1980) and the theoretical teachings about plant community-soil relationships of Drs. Min Hironaka and Maynard Fosberg at the University of Idaho, Moscow. Throughout this paper, habitat type to the phase level, plant association, and climax plant community are used interchangeably. The basic premise is that one habitat type phase can occur over more than one soil, but the converse is not true. Within a habitat type phase each set of functional soil forming factors will develop a soil specific to that set of environmental conditions. Therefore, a unique set of soils can be correlated with individual habitat types and phases of habitat types. The soils associated with one habitat type phase often show variation ranging from slight changes of characteristics within a soil series or series-phase taxonomic unit to possible changes of more than one Order. But most important to this model, one identifiable soil unit will only support one specific habitat type phase.

DISCUSSION

Both internal and external sets of independent factors affect the development of individuals in most all physical and biological systems. Nowhere is this more observable than in the wide variety of natural plant communities and soil horizonations. Jenny (1941) describes a set of five factors that characterize the formative elements for all soil development. Major (1951) felt that plant community composition on any given site is a similar function of the same five factors. These factors are: climate, in the sense of regional macroclimate; parent material, the basement rock or depositional material from which the soil originates; relief (topography), the slope, aspect, elevation, landform, and related ground water conditions; organisms, the micro- and macro-organisms of plant and animal species potentially available for site occupancy; and time, the zero point starting from the initiation of soil formation or since major disturbance to existing conditions. Jenny (1958, 1980) further elaborates on this concept with particular reference to the effects of plants as pedogenic (soil forming) factors. The "potential biota" for a site is independent of all other factors, but due to variation in physiological tolerance of species to microclimatic changes caused by natural

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successional processes, only a limited number of the potential species will successfully persist on a given site. Unlike plant community successional concepts, we consider soil as having only primary successional development.

Many taxonomies have been developed for both plant communities and soils, but little direct analysis of their interrelationships has been reported. A problem for analyses of this kind is that soil and plant community classifications are both artificial systems, developed for different purposes, and are not compatible in either scale or units. A second problem often encountered in soil-vegetation analysis has been the lack of sufficient data to allow for proper stratification of samples collected from widely varying geographic locations, parent materials, climatic regimes and histories, and disturbance histories. Daubenmire (1970) recognized the importance of soil factors to vegetation and strongly stated "those soil properties suspected of playing important roles in vegetation differentiation are not among the characteristics emphasized in soil classification." Soil moisture and temperature regimes, aeration, and nutrients are the important attributes for vegetation (Loucks 1962, Daubenmire 1970). Also, vegetation responds to both long-term and short-term environmental changes (Daubenmire 1956), particularly extremes of temperature and moisture, whereas, climatic pulses tend to have only a minor effect on soil formation processes. Although they are often evaluated during field data collection by the soil scientist, none of these attributes considered important for vegetation are adequately assessed for forested environments by current soil taxonomic systems.

The trend in recent studies has been to investigate the relationship of individual or multiple soil characteristics to differing plant communities. Hann (1982) qualitatively described a number of soil-parent material-environmental conditions in western Montana which related very well to differing successional communities and specific habitat types. Sondheim and Klinka (1983) identified significant correlations between soil characteristic-site physiographic attributes and plant associations. Tisdale and Bramble-Brodahl (1983) conducted a statistically based, intensive study of vegetation communities and soil along the Salmon and Snake Rivers. They concluded that a satisfactory set of abiotic soil-site variables could be developed to identify the habitat type of a site even though only seral vegetation might be present. Neiman (1986) identified differentiating relationships between physical soil characteristics and six highly similar habitat types of northern Idaho.

It is necessary in the following thought process to divorce oneself from Soil Taxonomy (USDA SCS 1975) and its structured soil classification units. Do not expect the soil variation to be adequately described by taxonomic units such as series or series-phase. In some instances, these units are not defined tightly enough for usage in this context, and in many more instances, the terms are being interpreted differently by various groups of soil professionals. The characteristics which separate one habitat type specific soil unit from

another may not be significant variables in soil taxonomic classifications. Or a finer level of group subdivision may be required than is currently identified by soil taxonomies. Problems with previous research in this subject area have been the selection of site and soil characteristics to be analyzed based on assumptions of their ecological significance, and, more often, the use of data sets from widely varying geographic and geologic origins. One must suppress, for the time being, the desire to attach ecological meaning to relationships unearthed by research and analysis.

An identifiable soil unit is defined herein as a polypedon (group of pedons) which has very similar physical and chemical characteristics throughout its genetic horization. A change in one or more of its characteristics must be accompanied by a change in habitat type phase. At this point in the development of the theoretical model, it is unknown how similar the variables must be in order to have only one habitat type phase supported by one soil unit. It is expected that the discriminating soil characteristic(s) and its amount of variation will change under various environmental conditions as found by Hann (1982) and Neiman (1986). The search must be for individual or reduced sets of physical or chemical soil characteristics that correlate with a habitat type phase. Large data bases will be required to demonstrate correlation rather than merely extraneous random data structure.

Huschle and Hironaka's cone model (1980) conceptualizes all above ground environments occupied by a single habitat type phase. The cone is subdivided from apex to base into climax plant community and all potential secondary successional communities, with early pioneer species communities dominating the base layer of the cone. In figure 1, the successional pathway visible on the face of the cone theoretically proceeds from five pioneer community types to three early-mid seral community types which reduce to two late seral types before returning to the climax association.

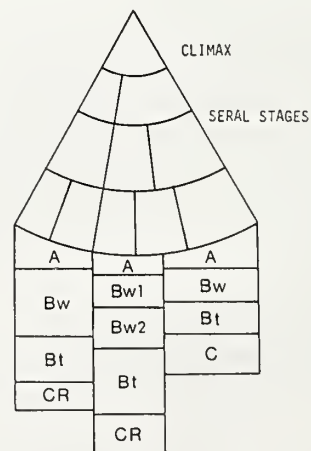


Figure 1--Conceptual model of secondary successional plant communities within one habitat type-phase and their relationship to habitat type-phase specific soil units.

If we then superimpose the various soils found within a single habitat type phase as a layer below the cone, we have a means of visualizing a variety of above and below ground environments. But the hypothesis remains that for each habitat type phase there exists a unique set of identifiable soils. Support for this theoretical change in soils with a change in habitat type phase can be found in the studies of Hann (1982), Sondheim and Klinka (1983), Tisdale and Bramble-Brodahl (1983), and Neiman (1986).

When we introduce a second cone model from an ecologically similar habitat type phase, we can show that many plant community types, particularly the early seral communities, are not unique to a habitat type. This is shown by community types 4 and 5 occurring in both habitat types I and II (fig. 2). The assumption often made is that highly similar plant communities have equivalent environments. And, although the equivalency of biological environments for plant reproduction and establishment cannot be disputed, factor compensation and species plasticity make allowances for what often are dissimilar physical environments.

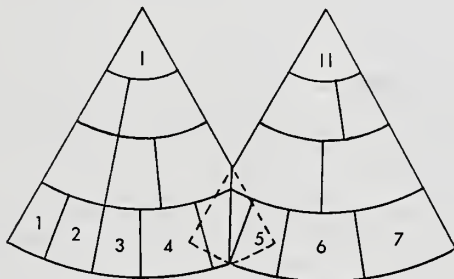


Figure 2--Conceptual model of seral plant communities in two closely associated habitat type-phases. The overlapped cones represent seral communities (4 and 5) common to both climax associations.

Our hypothesis can now be expanded to include specific seral communities that consistently relate to only one or a reduced set of habitat type phase specific soil units (fig. 3). Also, hypothetically, one seral community and one successional development pathway (sere) may relate to only one soil unit, but we have only anecdotal evidence for this at present. The distinctive power of this model is that although seral plant communities of closely associated habitat types are often very similar in both species composition and physiognomy, they will always occupy different soil units and can therefore be identified as communities having different climax endpoints.

Until further research can be undertaken, it is assumed that one cone model will be required for each habitat type phase and disturbance history. We also speculate that a cone for each vegetative layer (trees, shrubs, and forbs) as described by Steele (1984) would greatly increase the predictive accuracy of the model. Within each cone model, the seral communities and successional development pathways may change with variations in kind and/or intensity of disturbance. Existing data could be assembled into data bases from which one could assess portions of the above hypotheses, but much

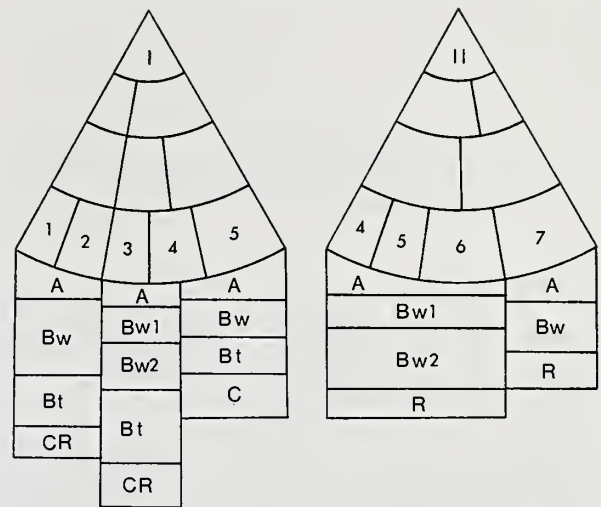


Figure 3--Conceptual model of seral plant communities in two closely associated habitat type-phases and their relationship to habitat type-phase specific soil units. Early seral communities 4 and 5 occur in both climax successions but occur over different soil units.

research in the form of data collection and analysis remains before practical applications can be confidently described. The implications of the models for repeatable stratification of environmental variations are very wide reaching in all areas of plant community research and management.

CONCLUSIONS

The concept that soil and vegetation both have a functional relationship to climate, parent material, relief, organisms, and time has led to the hypothesis that relationships also exist between soil and vegetation. Although they appear to respond to the same "functional factors," this cannot be extended to indicate that soil and vegetation are correlated on a one-to-one basis. The relationships between them are multifactorial and dynamic; the effect upon plant growth or reproduction of any one soil variable changes quantitatively and/or qualitatively with every variation in the complex of environmental factors. In Major's (1951) factorial approach to plant ecology, he concluded "...there are no universal correlations between vegetation and soil;...soil is not determined by vegetation, vegetation is not determined by soil; vegetation and soil develop concomitantly." Yet, it is exactly this concomitant development that provides quantifiable characteristics by which we can better understand the relationships between plant communities and soil-forming processes. Identifiable relationships can be demonstrated to exist between soils and vegetation.

The use of habitat types for refinement of silvicultural prescriptions and site productivity assessment has proven to be valuable to forest resource managers. Knowledge of the correlations between potential vegetation, soil, and site

characteristics within a specific geographic region will allow more accurate classification of any given site within that region to habitat type and phase. This will also improve the identification of highly disturbed seral vegetation stages, more accurately position them within their successional development pathway, and allow for greater accuracy in predicting site capabilities and response to disturbance.

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FLOOD-PLAIN SUCCESSION AND VEGETATION CLASSIFICATION IN INTERIOR ALASKA

Leslie A. Viereck

ABSTRACT: Twelve stages of forest succession on the Tanana River flood plain are described. Succession begins with invasion of fresh alluvium by willows and proceeds through a stage of shrubs and deciduous trees, to mature mixed-aged stands of white spruce, and finally, with the development of permafrost, to unproductive black spruce stands and bogs. A classification of the successional communities is given. Because of the formation of permafrost and resultant deterioration of the site, a classification based on successional communities may be more useful than one based on habitat types.

INTRODUCTION

The flood plain of the Tanana River in interior Alaska provides an excellent opportunity to examine successional processes in the taiga environment. Because of the active erosion and sand and silt bar formation of this glacial river, new surfaces are continually formed and available for invasion by plants, and all stages of succession from initial vegetation on recently deposited sediment to mature forest are readily available for study. In addition, the topography is relatively flat and the river sediment deposits relatively uniform so that the main state factor regulating change is time.

The successional sequence on the flood plain also provides an opportunity to address problems of classification of both seral and mature plant communities, and especially how white spruce communities are affected by the formation of permafrost in later stages of forest succession. In this paper, the Alaska vegetation classification system (Viereck and Dyrness 1980), which is based on current rather than potential vegetation, is used to classify the flood-plain vegetation. The system uses cover of the dominant vegetation layer and the dominant species in each of the important vegetation layers.

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Although succession on the flood plain proceeds as a continuum of vegetation development with time, we are able to recognize several relatively distinct stages in succession, each one on an older and slightly higher terrace of the river. Usually, the same age or stage of succession is found repeated frequently in an area, probably from simultaneous origins after episodal events such as severe flooding and sediment deposition and unusual seed years of some species. We also have found what could be considered distinct "turning points" in the successional sequence and have recently designed some of our research around these points (Van Cleve and Chapin 1986). In order of occurrence, these turning points in the flood plain succession are: (1) the stabilization of alluvium by early plant cover, (2) the formation of a complete vegetation canopy with a surface organic layer covering the mineral soil, (3) the shift from willow to alder dominance in the shrub canopy, (4) the shift in dominance from shrubs to deciduous trees, (5) the shift in dominance from deciduous to coniferous trees with the resultant establishment of feathermosses in the forest floor, and (6) the development of permafrost in the soil.

Previous papers (Van Cleve and others 1980; Van Cleve and Viereck 1981; Walker and others 1986) reported on ecosystem processes, nutrient cycling, and productivity in the successional sequence on the Tanana River flood plain. This paper will stress the classification and description of the vegetation of 12 stages of succession that occur commonly on the floodplain (fig. 1). These are modified from a previous paper in which eight stages were described (Van Cleve and Viereck 1981).

METHODS

I have been examining vegetation plots on the Tanana River for the past 25 years. Reconnaissance plots were established in 1964 and 1965 using a one plot-6 class cover estimate. In 1965 and 1966, permanent plots were established in 15 successional stands. Cover of low shrubs, herbs, mosses, and lichens was measured in 10 1-m² plots; shrub cover and density were measured in 10 4-m² plots; and each tree was measured and tagged in 500 or 1000 m² plots. These plots have been remeasured at about 5-year intervals. Additional information has been obtained from many other stands on the flood plain using a 20-point system of permanent plots described by Foote (1983). In addition to

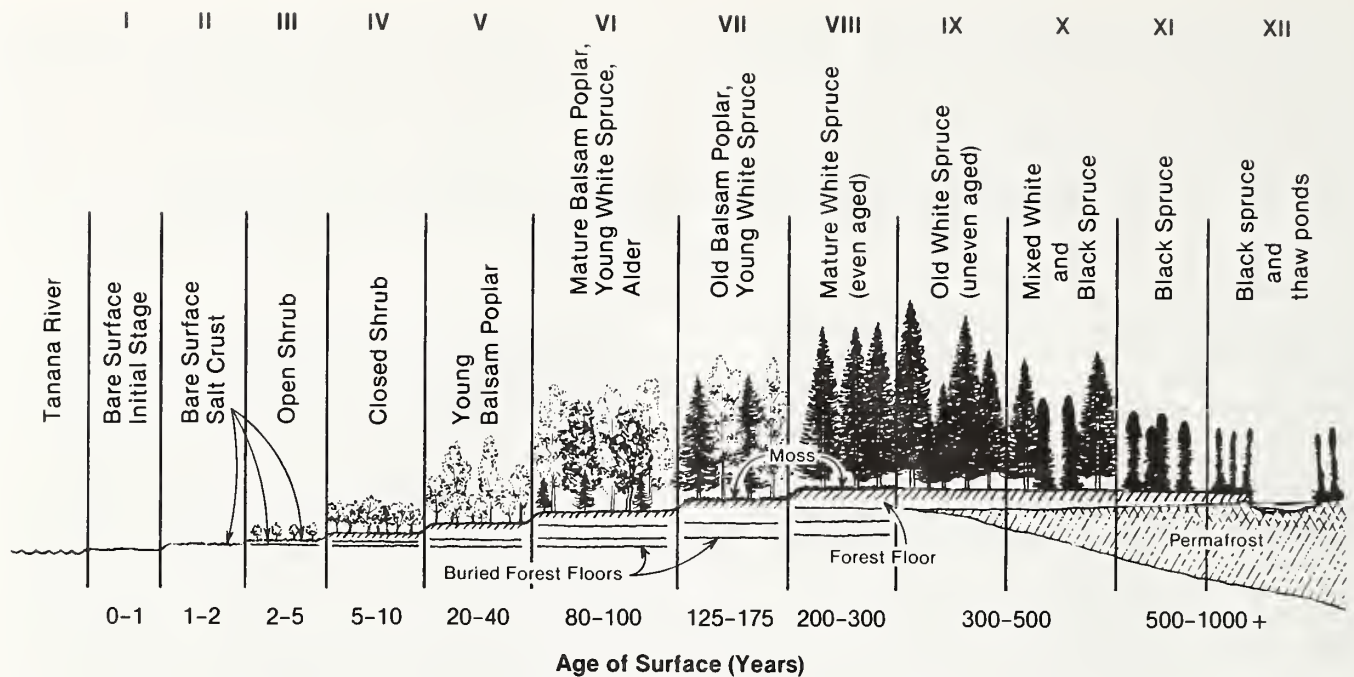


Figure 1--Cross section of 12 stages of vegetational succession on the floodplain of the Tanana River.

vegetation cover and tree and shrub density, above-ground tree biomass and annual productivity measurements have been obtained for some of the stands.

The units reported here correspond approximately to the community type used by most authors, but a rigorous vegetation analysis has not been used to determine the units. They have been subjectively selected as a result of my experience on the Tanana flood plain and examination of individual stand data from a number of measured stands.

RESULTS

Stage I. Bare Alluvium (no classification)

The recently deposited sediment bars are flooded during large portions of the summer. A few *Salix* and herbaceous species may become established during periods of low water, especially in late summer, but these pioneers are usually swept away or covered by silt during high water the next summer.

Stage II. Bare Recent Alluvium with Scattered Willow and Herbs (vegetation on these new surfaces is too sparse and transient to warrant classification)

Sediment surfaces that have accumulated to a height sufficient to be free of flooding for one or more years (about 2 m above the lowest winter river levels) tend to develop an evaporative crust of calcium sulfate (gypsum) and calcium carbonate on the surface. Although this salt crust may somewhat inhibit germination and

establishment of some species, this is the stage at which plant colonization begins. Species colonizing these sites include *Salix interior*, *S. alaxensis*, *S. nova-anglaea*, *Populus balsamifera*, and the herbs, *Equisetum palustre*, *E. arvense*, *E. variegatum*, *Juncus alpinus*, *Hedysarum mackenzii*, *Triglochin palustris*, and *Carex concinna*. Some of these young stands may persist but most are destroyed by flooding and alluvial deposition. Once the *Salix* species are well established, they can withstand both flooding and silting and often contribute to the siltation process by slowing down the flow of the sediment-laden water.

Stage III. Open Young Willow Shrub (open *Salix* spp./*Equisetum* spp. community)

An open shrub stage, 0.5 to 1.5 m in height, occurs for 2 to 5 years after the establishment of willows. The most important species are *Salix interior*, *S. alaxensis*, *S. brachycarpa*, *S. nova-anglaea*, and *S. lasiandra*. Although the stand is frequently flooded, an herbaceous layer develops beneath the willows; it consists primarily of *Equisetum variegatum*, *E. palustre*, and *E. hiemale*. Other herbs include *Carex concinna*, *Triglochin palustre*, *Castilleja caudata*, *Solidago canadensis*, *Antennaria pulcherrima*, *Juncus alpinus*, and *Spiranthes romanzoffiana*. At this stage seedlings of *Populus balsamifera*, *Alnus tenuifolia*, and *Picea glauca* often become established, but *P. glauca* may not persist into later stages because of the heavy silting that occurs.

Cover of the shrub layer varies from 15 to 50 percent, and the herbaceous layer varies from

under 10 percent after flooding to nearly 100 percent during summers when the stand is not flooded. At this stage, no significant development of the litter layer occurs because of the low biomass of the leaf litter and its frequent burial by silt. This stage of succession is found on terraces usually 2 to 2.25 m above the winter level of the river.

Stage IV. Closed Alder and Willow Shrubs (closed Alnus tenuifolia-Salix spp./Equisetum spp. community)

As the shrub canopy begins to close, at a height of 2 to 3 m, Alnus tenuifolia becomes co-dominant with the Salix spp. in the canopy. During the development of this stage, a major thinning of the willow stems usually takes place caused by a combination of browsing by snowshoe hares and overtopping of the willows by alders. Some species, such as Salix interior and S. brachycarpa, are completely eliminated, but others, especially S. alaxensis and S. novae-anglaeae, are able to persist in the dense Alnus canopy, which may reach to heights of 10 m toward the end of this stage. With the closure of the shrub canopy, the herbaceous layer becomes more depauperate, but it generally has small amounts of Equisetum arvense, E. pratense, E. palustre, Moerhingia laterifolia, and Calamagrostis canadensis. White spruce seedlings may become established in this stage.

Cover of the shrub layer is usually 80 to 100 percent, but herbaceous layer cover is usually under 25 percent. At this stage, a heavy leaf and woody litter develops on the forest floor, with litter fall of as much as 250 g/m²/yr. The litter layer is occasionally buried by sediment deposition during flooding, however. Productivity of these stands is high, on the order of 4000-4750 kg/ha/yr (Van Cleve and others 1971) and amounts of N in the system increase markedly during this period through N-fixation by alder root nodules. These closed shrub stands are usually on terraces that are 0.5 m above the stage III, or 2.5 to 2.75 m above the winter low-water level, indicating that sediment deposition from flooding is still a factor during their development. These closed shrub stands dominate for 10 to 20 years and occupy relatively large areas on the flood plain.

Stage V. Open Balsam Poplar With Dense Alder Understory (open Populus balsamifera/Alnus tenuifolia/Equisetum spp. community)

At about 20 to 30 years after establishment of vegetation on alluvial deposits, Populus balsamifera stems reach through the shrub canopy and begin to dominate the sites. The tree canopy remains open, and the cover of Alnus tenuifolia begins to decline from the stage IV levels. The less shade-tolerant willows usually drop out of the stands or persist only as scattered individuals. More shade-tolerant shrubs, such as Rosa acicularis and Viburnum edule, become established in the understory. The herb layer

remains relatively scattered and is dominated by Equisetum arvense and E. pratense. Some herbaceous species that will persist into the later conifer stages begin to appear during this stage--Pyrola asarifolia, P. segunda, and Geocaulon lividum.

Stage VI. Closed Balsam Poplar with Alder Shrub Understory (closed Populus balsamifera/Alnus tenuifolia/Rosa acicularis/Equisetum spp. community)

In mature balsam poplar stands where the canopy has closed by crown expansion, cover of the understory alder shrub layer is reduced. In addition, both Rosa acicularis and Viburnum edule become more important in a low shrub stratum. The herbaceous layer is similar to that found in stage V except that total cover is somewhat greater. The shrub layer cover is about 50 percent and herbaceous cover ranges from 25-50 percent. Tree basal area reaches 35 to 40 m²/ha, and above-ground tree productivity reaches a maximum for the successional sequence on these sites--as high as 9500 kg/ha/yr in 50- to 75-year-old stands (Viereck and others 1983). A heavy litter layer also develops in these stands. Examination of the soil profile reveals many buried organic layers, indicating that sediment deposition from flooding is still common. The terraces on which these stands are found are 3 to 3.5 m above the winter river levels, and flooding occurs about once per decade. This deciduous tree stage may persist for 100 years before it is replaced by white spruce forests.

Stage VII. Mixed Balsam Poplar and White Spruce (closed Populus balsamifera-Picea glauca/Alnus tenuifolia/Equisetum spp. community)

This mixed balsam poplar and white spruce stage is transitional between the deciduous forest and the conifer forest stages. It marks an important turning point in the successional sequence on the flood plain. White spruce may become established as early as stage IV and develop concurrently with the balsam poplar, but more commonly white spruce seedlings first come in under the young balsam poplar canopy. In the mixed poplar-spruce stands, the canopy of balsam poplar is once again open; heavy mortality in the poplars is usual, especially as they reach 100 years of age. White spruce remains under the balsam poplar canopy, but it may have as much as 50 percent of the tree canopy cover. In this stage, the Alnus tenuifolia shrub cover is usually as low as 25 percent, and Rosa acicularis and Viburnum edule are common.

Deciduous leaf and twig litter form a thick layer on the forest floor. On downed logs and under some of the larger spruce, however, patches of feathermosses become abundant in later successional stages. Once white spruce reaches dominance in these stands, numbers and cover of balsam poplar rapidly decrease, primarily as a result of stem rot and wind breakage.

Consequently, transitional stands of this nature are not widespread on the flood plain.

Stage VIII. Mature Even-aged White Spruce Stands (closed Picea glauca/Rosa acicularis/Linnaea borealis/Hylocomium splendens community)

Most of the 100-year-old white spruce stands on the Tanana flood plain have a closed canopy of more than 75-percent cover. A few old, usually decadent balsam poplar are scattered throughout the stand. As a consequence of the dense tree canopy, the alder shrub layer is usually reduced to an occasional clump. Most stands, however, have a well-developed shrub layer of Rosa acicularis and an occasional Viburnum edule. The low shrub and herb layers together comprise about 25-percent cover and are composed primarily of Linnaea borealis, Equisetum arvense, E. pratense, Geocaulon lividum, Pyrola secunda, and P. asarifolia. Hylocomium splendens provides most of the moss cover, which approaches 100 percent, but Rhytidiadelphus triquetrus can be an important part of the moss layer in some stands.

White spruce stands on the Tanana flood plain are usually at least 3.75 to 4 m above the winter low-water level, and flooding is infrequent. Tree density may be as high as 2000 tree/ha in the younger stands but tends to be reduced to 500 to 750 trees/ha in older stands. Average diameters of the spruce are about 30 cm, and basal area ranges from 30-60 m²/ha. Annual tree productivity is high, reaching to 5400 kg/ha per year (Van Cleve and others 1980). These stands are the prime commercial forest stands on the floodplain.

Stage IX. Old, Uneven-Aged White Spruce Stands (open Picea glauca/Alnus crispa-A. tenuifolia/Vaccinium vitis-idaea/Hylocomium splendens community)

On older terraces, generally located well back from the river, the white spruce stands are more open and uneven aged. Juday and Zasada (1984) have shown the change in structure and age of white spruce on different-aged terraces on Willow Island on the Tanana flood plain. Paper birch (Betula papyrifera) may occur in highly variable numbers in these stands. The average white spruce cover is as low as 30 to 50 percent, and tree ages range from 130 to 350 years. Both Alnus crispa and A. tenuifolia are the dominant tall shrubs, with cover ranging from 10 to 80 percent, depending in some measure on the density of the tree canopy. Other commonly occurring shrubs are Rosa acicularis and Viburnum edule. The dominant species in the low shrub-herb layer is Vaccinium vitis-idaea with lesser amounts of Linnaea borealis, Equisetum arvense, Cornus canadensis, and Geocaulon lividum. Moss cover is dense, primarily Hylocomium splendens, but other mosses such as Pleurozium schreberi and Rhytidiadelphus triquetrus are also common.

These stands are located on high river terraces that are only infrequently flooded. A layer of intermittent permafrost is usual in most of the stands, marking an important turning point in the successional sequence. Tree growth is slower--and thus forest productivity lower--than in the younger, first-generation spruce stands on the flood plain.

Stage X. Mixed White and Black Spruce (open Picea glauca-P. mariana/Ledum groenlandicum-Vaccinium vitis-idaea/Hylocomium-Pleurozium community)

Mixed stands of white spruce and black spruce occur occasionally on the Tanana River flood plain and are transitional between the stands on the young active flood plain and those of the older terraces. The stands are open with canopy cover as low as 25 to 50 percent. Paper birch also generally occurs in small numbers in the tree layer. The spruce have diameters averaging 20 cm and are uneven aged, with ages ranging from 150 to 250 years. The tall shrub layer is sparse and is made up of Alnus crispa, Rosa acicularis, and Salix glauca. Low shrubs are abundant with a cover of more than 50 percent, with Ledum groenlandicum and Vaccinium vitis-idaea being the most abundant. Empetrum nigrum, Linnaea borealis, and Vaccinium uliginosum also occur in smaller amounts. Common herbs include Equisetum arvense, Geocaulon lividum, Cornus canadensis, Calamagrostis canadensis, and Arctagrostis latifolia. Moss cover of Hylocomium splendens and Pleurozium schreberi is well developed, with a total cover of about 75 percent. Lichen cover averages 15 to 35 percent and is comprised primarily of Peltigera aphthosa, P. canina, Cetraria islandica, and several species of Cladonia.

These stands are always underlain by permafrost, and the active layer may be shallow, with thicknesses of 50 to 60 cm being most common. Tree growth is slow, and forest productivity is low.

Stage XI. Open Black Spruce (open Picea mariana/Ledum groenlandicum/Hylocomium splendens community)

Stands of black spruce are common on the oldest terraces of the active flood plain. Black spruce is the dominant tree, but scattered white spruce, tamarack (Larix laricina), and paper birch may also be present. Although tree density is high (2400 stems/ha), the canopy is usually open, with cover of 40 to 60 percent. Tall shrubs, primarily Alnus crispa and Rosa acicularis, are scattered in the stand, with cover of about 10 percent. A low shrub stratum of Vaccinium vitis-idaea, Ledum groenlandicum, and Empetrum nigrum forms a nearly continuous cover. Herb cover is low; Equisetum scirpoides, Geocaulon lividum, and Calamagrostis canadensis are the most common. A thick mat of Hylocomium

splendens is nearly continuous. Sphagnum spp. often occur in wet depressions in the stand.

These stands are closely underlain by permafrost, and the active layer is usually less than 60 cm thick. Forest productivity is low. For one stand, we found that the annual above-ground forest productivity was only 75 g/m² (Viereck and others 1983).

Stage XII. Black Spruce, Thaw Ponds, and Bogs (classification of the mosaic of vegetation types on the oldest terraces is beyond the scope of this paper)

The final stage of succession on the Tanana flood plain is represented by terraces that are a mosaic of open or woodland black spruce stands similar to those of stage XI interspersed with depressions or small ponds. These low, poorly drained areas originate in the melting of the underlying permafrost, which is rich in ice lenses or wedges (Benninghoff 1952; Drury 1956). Depressions are often water-filled or may be in the process of filling and bog formation. A wide variety of vegetation types occurs in these areas, depending on the stage of development of the thaw pond or bog. Sphagnum mosses and several species of Carex and Eriophorum are the major species. Three community types--a sedge meadow, an Eriophorum vaginatum tussock, and a Sphagnum bog type--have been described on older river terraces in the general area of the Tanana River (Calmes 1976).

CONCLUSIONS

As discussed by Steele (1984), when successional communities are classified, grouping successional communities occurring within one ecosystem (habitat) type is best. Whereas the site-type classification is based on climax ecosystems with time as a relative constant, successional classification should hold the environment relatively constant and examine communities over a time sequence (Arno and others 1986). The successional time should be characterized by the communities rather than by years since the beginning of the successional sequence.

In the sequence I have described for the Tanana River flood plain, the main variable is time: time since the formation of the alluvial deposit and the establishment of the first vegetation on the new surface. This sequence then should fit the criteria for a successional sequence within a single habitat type. Certain environmental characteristics also change with time, however, either directly or indirectly as a result of the developing vegetation. The three most important environmental changes on the Tanana River flood plain are the height above the river and, thus, the frequency of flooding; access to the underlying water table for water and nutrients; and the development of permafrost in the later stages of succession as a result of the thick moss layer on the forest floor.

The permafrost layer causes profound changes in the site, tending to convert productive white spruce sites to low-productivity black spruce sites. The classification of the soil actually changes with the development of permafrost. Young soils on the active flood plain are in the Salchaket series (Typic Crofluvents). When permafrost enters the soil, however, they are classified in the Tanana, Bradway, or Goldstream series as Pergelic Cryaquepts, a change in soil orders from Entisols to Inceptisols (Furbush and Schoephorster 1977). With the impervious permafrost layer, the soils become waterlogged even though they were previously well drained. Soil temperatures in the stands are low, decomposition slows, and nutrients become limiting to tree growth (Van Cleve and others 1980). Productivity of these sites is low and concentrated in the moss layer.

How should this situation be handled under the ecosystem type classification? What is the "climax" type for these sites? Is it the productive mature white spruce stand, the unproductive black spruce stands, or the black spruce-bog mosaic found on the older terraces? From the point of view of managers, a classification based on the successional vegetation might be more useful than one based on habitat type. Logically young productive white spruce stands on the flood plain would need a different management strategy than older less productive stands underlain by permafrost (Zasada 1984). This logic has been shown on Willow Island on the Tanana River flood plain, where three different ages of white spruce stand were experimentally logged in 1983. The reaction of vegetation and soils to logging was very different in three different ages of white spruce stands (Dyrness and others, in press). In a previous paper (Viereck and others 1986), we separated the flood-plain vegetation into two main site types: the white spruce type on the active flood plain and the black spruce-permafrost type on the older terraces. This might be useful for developing a more detailed classification even though it does not rigidly fit into the site type classification based on "climax" vegetation.

SUMMARY

On the Tanana River flood plain, distinct successional communities can be recognized and classified. They begin with open willow stands on recently deposited alluvium and proceed through shrub and deciduous tree stages to productive white spruce stands. With time, permafrost develops in these mature white spruce stands, and they are replaced by low-productivity black spruce stands and eventually, on older terraces, by a mosaic of black spruce and bog communities. Classifying these sites by habitat type is difficult unless the system is modified to recognize the deterioration of the site when permafrost develops. A classification that recognizes the successional communities leading to mature white spruce stands, the various ages

of the white spruce stands, and the deterioration of the site with the developing permafrost might be the most useful to forest managers.

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OPERATIONAL USE AND EVOLUTION OF A PLANT ASSOCIATION CLASSIFICATION

Miles A. Hemstrom and Michael Frazier

ABSTRACT: Competitive interactions between Douglas-fir and salmonberry are a major silvicultural concern in the Oregon Coast Range. A plant association classification provided an initial focus on sites where intense competition is likely. Subsequent examination at a level below the plant association revealed topographic variants of salmonberry-dominated plant associations where competition is most severe. Topographic classes will be useful in predicting development of intense competition and will be incorporated in future revisions of the plant association classification.

INTRODUCTION

Plant association classifications, particularly when actively used for natural resource management, cannot be static entities. Application frequently leads to views of the vegetation/environment complex in ways and at levels of detail not possible to incorporate in the initial classification effort. The classification is constantly being refined to make it more useful and meaningful. The types and levels of use will guide the direction and degree of evolution. An example from the Siuslaw National Forest illustrates this process.

The Siuslaw National Forest has abundant natural resources, including fish, water, wildlife, and timber. Climate and abundant resources make the Forest one of the most productive areas in the world for timber and fish. Accurate resource information is critical to program and project planning. Plant associations are being actively used as key stratification elements for both basic resource inventory and as predictive tools. In this paper, we focus on their use in the reforestation phase of intensive timber

management, especially for predicting the severity of competition between shrubs and conifers in the salmonberry associations.

Physical and Vegetative Setting

The Siuslaw National Forest spans about 630,000 acres of the Oregon Coast Range between Tillamook and Reedsport. The climate is distinctly maritime with abundant winter precipitation, relatively dry summers, and mild temperatures throughout the year. Most precipitation falls as rain from October through March and yearly averages range from 80 to over 150 inches (U.S. Department of Commerce 1965). Mean minimum winter air temperatures seldom average below freezing and mean maximum summer air temperatures rarely average above 80 degrees Fahrenheit (Johnsgard 1963).

Interbedded sandstones, siltstones, and mudstones in the southern half of the Forest have been highly eroded, resulting in a steep, highly dissected topography. Relatively resistant igneous bedrock, most common in the north half of the Forest, lies under the highest peaks, which rise to nearly 3000 feet. Stony, sandy loam inceptisols are common in steep, colluvially active topography. Ultisols of deep clay have developed on more stable inland topography.

Two conifer series occur on the Forest (Hemstrom and Logan 1986). Sitka spruce and western hemlock are the climax species in the Sitka spruce series found near the Pacific Ocean where the maritime climatic influences are most pronounced. The first major ridges inland reduce maritime climatic influences, leaving western hemlock the dominant climax species in the western hemlock series. Western redcedar is potentially a sub-dominant climax species throughout the area. Douglas-fir and red alder, alone or in combination, dominate existing natural stands. Most natural stands are about 110 years old, a result of a series of wide-spread fires in the mid-nineteenth century. Climax stands are exceedingly rare.

Hemstrom and Logan (1986) described 23 plant associations on the Forest. Associations in which salmonberry is common fall into three major groups, as moisture conditions range from mesic to xeric.

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Salmonberry associations--Salmonberry plant associations dominate the wettest sites, generally on lower slopes and in concave topography. The dense shrub layer persists for an indefinite period of time and dominates early seral communities. Conifer establishment can be difficult and succession to climax very slow. Red alder and scattered conifers dominate the canopy on most sites. Both crop trees and salmonberry grow rapidly during the first five years in plantations (fig. 1). Mean crop tree height exceeds mean salmonberry height by year five following harvest.

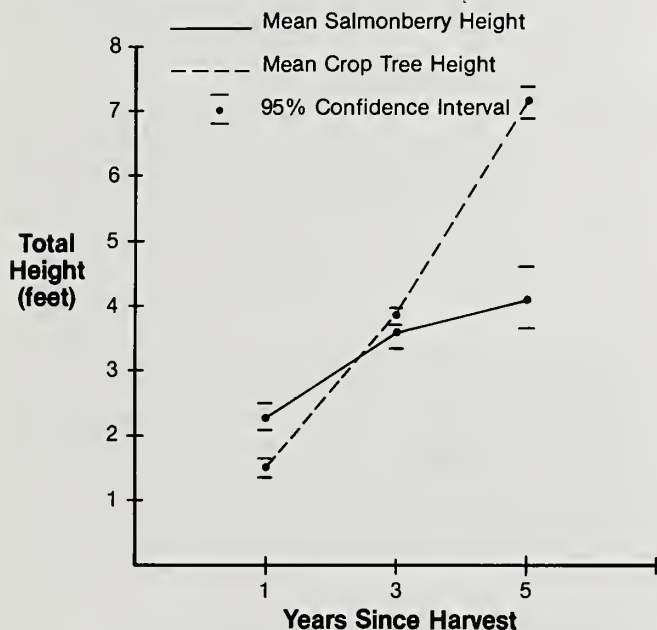


Figure 1--Mean salmonberry and crop tree height at one, three, and five years following harvest in salmonberry associations.

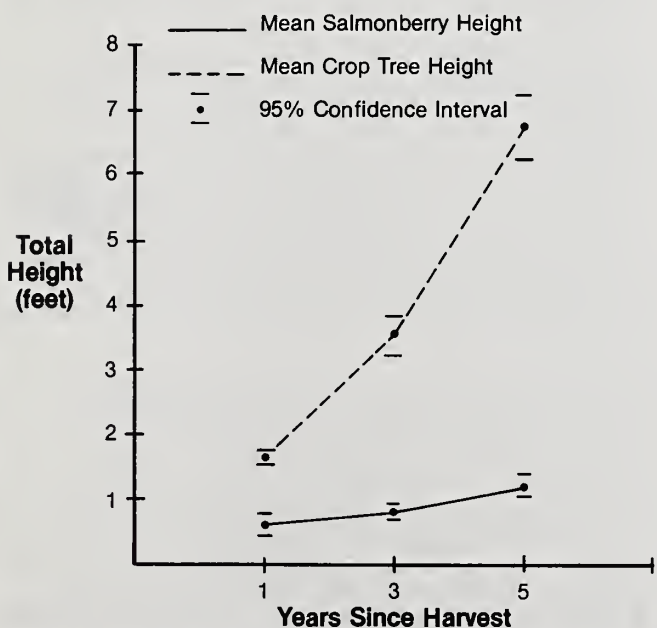


Figure 2--Mean salmonberry and crop tree height at one, three, and five years following harvest in swordfern associations.

Swordfern associations--Swordfern plant associations are common on more well-drained, middle and upper-slopes. Salmonberry may occur in early seral communities, but is not as vigorous. Well-stocked Douglas-fir stands, often containing red alder, dominate most sites. Crop trees are generally taller than salmonberry in most plantations by five years following harvest (fig. 2).

Salal associations--Salal plant associations are found on relatively dry sites. Red alder and salmonberry are not abundant. Most stands consist of nearly pure Douglas-fir. Crop trees are substantially taller than salmonberry in plantations by five years following harvest (fig. 3).

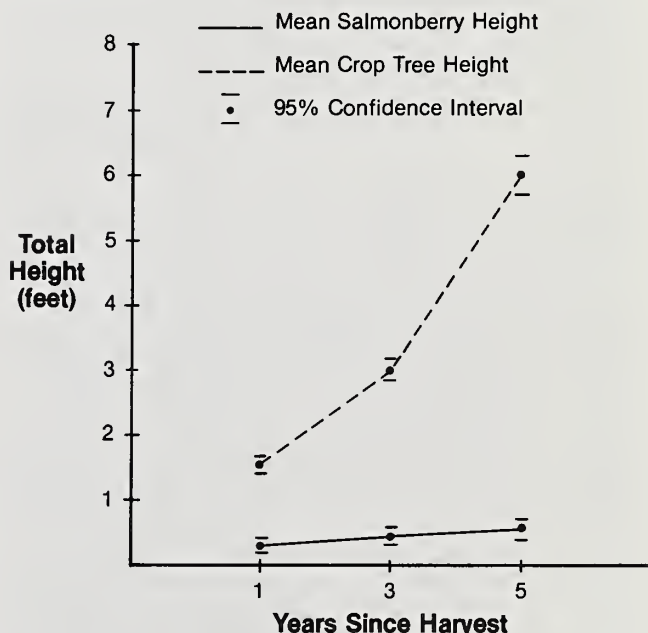


Figure 3--Mean salmonberry and crop tree height at one, three, and five years following harvest in salal associations.

Management Setting

Early competition between conifers and other vegetation is a major concern in this area of high productivity. Planted conifers have rapid juvenile height growth. They will eventually dominate and shade out competing shrubs and hardwoods, unless they are weakened by too long a period in the shade. This situation can occur either as a simple result of competition or because trees have fallen behind for other reasons, including animal damage.

The most significant periods when competition between conifers and shrubs or hardwoods may produce unacceptable seedling mortality include:

1. salmonberry and associated vegetation up to five years following harvest. Rapidly resprouting shrubs create heavy early competition and animal cover, influencing crop trees before they are established.

2. rapidly growing red alder over-topping established conifers five to ten years following harvest. This situation may develop on different areas than salmonberry competition.

In this paper, we will focus on early competition between conifers and salmonberry. Plantation establishment in salmonberry-dominated areas has sometimes seemed an intractable problem, especially given the administrative loss of chemical herbicides. Even when herbicides are available, areas where the problem exists often cannot be treated because of proximity to open water. Manual methods have sometimes required repeated treatment because of rapid sprouting. Experience with this situation has led managers to expensive preventive measures like pre-burn herbicide applications or slashing treatments. Most managers believe that plantation establishment in these zones will be very difficult without burning or herbicides or both. While this is perceived to be the case on a large portion of salmonberry-dominated areas, many areas have been successfully managed without extraordinary measures. The major problem has been predicting the locations of difficult areas.

Silviculturists on the Siuslaw National Forest have worked for some time to understand the complex competitive situation in early plantation development. Believing that stratification by plant association would aid this understanding, they incorporated plant association into the design of a reforestation survey system. This system is an organized method for collection and storage of data on surveys taken in the course of reforestation examinations typically performed at one, three, and five years following site preparation. The system is common across the Forest. Data collected for each plot include plot location (on a grid for each survey area), aspect, slope, stocking, crop tree attributes (species, height, height increment, animal damage), height and cover for major shrub and herb species. Plant association for each plot is included from a map prepared before harvest. The grid of plot locations is flagged in the field and used, as much as possible, in subsequent plantation examinations. Treatment history, in the form of codes for release treatment and date of the latest tree planting effort, are included for each plot. Intensity of prescribed burns was recorded in more recent examinations. The data set does not yet contain a substantial amount of information on burn intensity. The data are organized in a data file and updated yearly. There are over 50,000 plots in the file as of August 1987.

The information in the database is an extensive sample of vegetation development after various treatments on all the environments represented across the Forest. It offers an opportunity to examine reaction of vegetation to treatment across a wide range of environment and to develop predictive tools. The salmonberry-conifer competitive interaction was the focus of initial efforts to use the data set to develop predictive tools. The specific objective of these initial

efforts was to learn whether there are variants within the salmonberry plant associations which could be identified by site features and where competition is so severe that crop tree establishment is improbable without extra measures.

METHODS

The approach we used generally involved two steps:

1. identifying a subset of reforestation survey plot data where competition from salmonberry was apparently severe and where crop tree performance was unacceptable,
2. examining the plots within the subset in some detail to discover whether they had common attributes that would help predict the severe competition conditions.

Identification of the Severe Competition Subset

The first step in the process of identifying a subset where salmonberry competition was apparently severe involved focusing on five-year reforestation survey data. Plantations at age five have gone through the initial establishment period. The rate and direction of vegetation succession has become obvious and initial crop tree success is apparent. This five-year set of data from Mapleton District contained about 9400 plots.

The next step in screening the data involved eliminating plots from areas that had been replanted or inter-planted with conifers after the failure of an initial planting. This eliminated plots (about 24 percent of the five-year data set) where the conifers might be substantially younger than the shrubs.

A similar screen involved eliminating plots from areas previously treated with manual, chemical, or other means to reduce shrub competition. This eliminated plots (about 14 percent of the five-year data set) where shrub height reflected treatments. This selection may also eliminate some sites where salmonberry grows most rapidly and which, therefore, might have been treated to reduce shrub competition. To ensure that these sites were sampled, we included some three-year reforestation survey plots from areas subsequently released.

We isolated a group of plots from salmonberry plant associations where apparent competition between conifers and shrubs was severe enough that either seedling mortality was high or most seedlings were over-topped by shrubs at age five. We assumed that salmonberry less than 4 feet tall and <50 percent cover at year 5 does not pose survival problems for conifers, since mean conifer height at age five exceeds 4 feet (fig 1). We grouped plots into subsets where salmonberry cover was incrementally increased from at least 50

percent to at least 70 percent and salmonberry height was incrementally increased from greater than 4 feet to greater than 7 feet. The resulting sets of plots were a series in which salmonberry cover and height increased from at least 50 percent and 4 feet to at least 70 percent and 7 feet. For each of these sets, we created frequency tables showing crop tree presence and height, salmonberry cover and height, and the difference in height between crop trees and salmonberry.

We examined the trends of crop tree presence and height and difference in height between crop trees and salmonberry among the sets of plots as salmonberry became more vigorous. Percent of plots without conifers is significantly higher ($p < 0.01$) with each salmonberry height increment of 1 foot above 4 feet. Salmonberry of at least 50 percent cover and at least 6 feet tall at year five is associated with significant ($p < 0.01$) increases in conifer mortality and, less clearly, with changes in conifer height growth. Increases in salmonberry cover above 50 percent were not associated with significant changes in mean crop tree height or the percent of plots without crop trees.

We chose the subset where salmonberry cover is greater than or equal to 50 percent and height is greater than or equal to 6 feet to pursue site attributes associated with vigorous salmonberry and unacceptably low conifer survival. The majority (64 percent) of plots in this set lack conifers. Salmonberry is taller than crop trees in over half (54 percent) of the plots which contain trees (fig. 4).

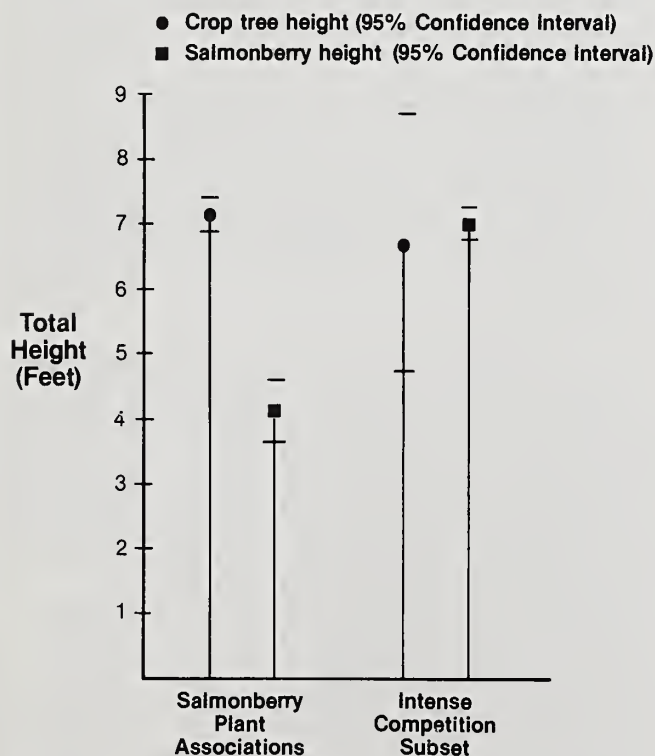


Figure 4--Mean salmonberry and crop tree height at year five following harvest in the salmonberry plant associations as a whole and in the intense salmonberry competition data set.

We recognize that salmonberry vigor and conifer height and survival lie along a continuum. Definition of "severe" salmonberry competition is somewhat arbitrary. From a management perspective, conifer survival to year five in the subset we chose is unacceptable. This set of plots contains 9 percent of all five-year plots where salmonberry had not been released and could be said to represent the worst 9 percent of the salmonberry association group spectrum.

Detailed Examination for Common Attributes

The conditions which allow salmonberry to reach at least 6 feet in height and at least 50 percent cover could be environmental, the result of management activities, or both. Slash burning, for example, has long been believed to slow salmonberry recovery. Cool, spotty burns could allow rapid salmonberry recovery. Poor burns might well be associated with particular environmental conditions, such as slope, aspect, and topographic position.

All of the reforestation surveys in the vigorous salmonberry data set were relocated in the field and on aerial photographs. A set of location and topographic attributes was identified for each plot, including: geomorphic zone (Berry and Maxwell 1981), distance from the ocean, aspect of the major slope on which the plot is located, plot position on the major slope (ridge, upper slope, middle slope, lower slope, bottom), plot elevation, and local topographic features. Local topographic features pertained to the immediately adjacent slope which feeds ground water directly into the plot area. Local topographic information included: distance to the drainage bottom, distance to the top of the slope, slope steepness, slope aspect, and whether the topography was concave, flat or convex in the horizontal and vertical planes. A total of 187 plots were relocated and examined.

RESULTS

Local topographic factors were the most consistent descriptors of the vigorous salmonberry plot set. Most of the plots (95 percent of the relocated plots) fell into one or more of four classes (fig. 5). Over half of the plots (53 percent) were in the riparian fringe. We defined the riparian fringe to be within 100 feet of the stream bottom or less than 25 percent of the distance up the drainage slope from the bottom.

Among plots not found in the riparian fringe, a substantial portion (32 percent) were on steep slopes facing west, northwest, north, northeast, and east. Steep slopes were defined to be over 50 percent slope. While all aspects were about evenly represented in the total five-year data set (fig. 6), very few of the relocated plots were on west aspects (fig. 7). If we eliminate west aspects, this topographic situation describes 30 percent of the relocated plots.

Eight percent of the relocated plots were in topographic depressions outside steep, northerly aspects and the riparian fringe. On these sites,

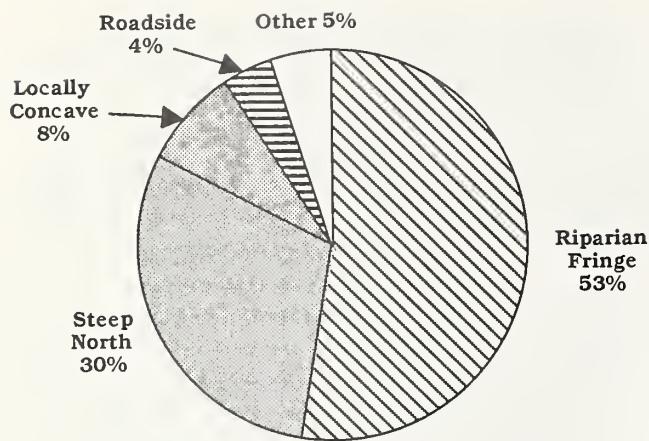


Figure 5--Percent of relocated reforestation survey plots in salmonberry associations falling into four topographic categories.

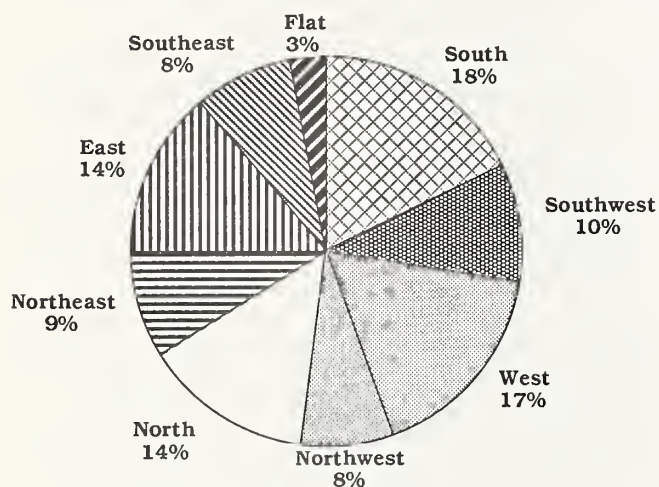


Figure 6--Distribution of aspect in all five-year reforestation survey plots.

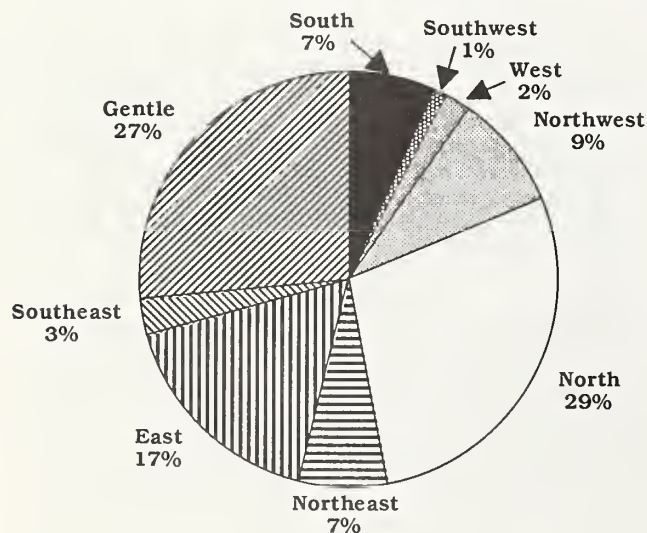


Figure 7--Distribution of aspect in relocated reforestation survey plots from the intense salmonberry competition data set.

micro-relief was concave in either the horizontal or vertical planes or both.

Another group of plots (4 percent of the 187 plots) were immediately adjacent to and downhill from a road or landing.

The remaining plots (5 percent of the relocated plots) did not form a discernable pattern, given the field attributes we measured. We suspect that these may be on sites with high ground water tables from seeps, on sites in shade during winter as a result of their large-scale topographic location, or on sites shaded by an adjacent stand edge resulting from timber harvest.

DISCUSSION

Our approach is descriptive, rather than experimental. For this reason, we cannot reach firm conclusions about why salmonberry is so vigorous in the areas we have described. Nor can we say with certainty that competition from salmonberry is the cause of poor conifer performance. However, we can develop hypotheses about the factors contributing to the coincidence of vigorous salmonberry growth and poor conifer performance in each of the four topographic conditions.

Lower slopes in the riparian fringe receive abundant sub-surface moisture from upslope. Salmonberry requires abundant soil moisture for optimum development. Douglas-fir, the major conifer species, does well with abundant, but not excessive, soil moisture. Soil moisture on lower slopes may occasionally be excessive for optimal Douglas-fir growth (Perry 1984). The competitive balance may shift in favor of salmonberry as a consequence of optimal height growth in salmonberry and possibly reduced Douglas-fir height growth. Topographic shading in narrow drainage bottoms may reduce photosynthetic output of Douglas-fir during winter when salmonberry has lost its leaves. Lower slopes on the riparian fringe often do not burn well or are protected from fire during slash burns, allowing salmonberry to get a rapid start following poor site preparation.

Steep, northerly facing slopes are topographically shaded during the winter when salmonberry is leafless. Direct solar radiation goes to zero by early November on north-facing slopes over 50 percent at 45 degrees north latitude. Net photosynthesis is relatively high throughout the winter at lower elevations in western Oregon (Waring and Franklin 1979). Winter photosynthesis during the period when salmonberry lacks leaves may be critical for conifer growth in severe competition situations. Conifers on sites which receive no direct solar radiation during winter can use only relatively low levels of indirect radiation for photosynthesis. In fact, conifers were shorter in this topographically shaded subset than in the riparian fringe subset ($p < 0.1$), but salmonberry height was not significantly different (fig. 4).

Soil moisture conditions in concave topography may be similar to those in the riparian fringe. The sample data set is too small to draw any inferences about relative conifer and salmonberry heights. While moist, concave topography may be a relatively minor part of the severe salmonberry competition situation on Mapleton District, it might be important in other areas of the Oregon Coast Range.

Moisture conditions likely also play a part in areas adjacent to and downhill from roads and landings. Soils of both roads and landings are compacted. Precipitation runs off, increasing water availability in adjacent soils.

While we cannot make conclusions about cause and effect, our approach is useful. We have formulated working hypotheses about the conditions associated with intense salmonberry competition on the Mapleton District. These hypotheses should be tested by sampling sites not included in our data to see if those that fit one of our four topographic classes in salmonberry associations are indeed sites with intense salmonberry competition.

Another follow-up investigation should involve experimental manipulations or more closely controlled comparisons to test specific parts of the hypothesis. For example, the importance of topographic shading could be examined by comparing two areas with identical plant association and site factors, with one shaded in winter by adjacent uncut timber and the other open to winter sun.

Salmonberry plant associations as a whole indicate sites with a narrow window of reforestation opportunity. Outside the most vigorous salmonberry sites, delays in stand establishment from poor planting stock and unpredicted animal damage can make stand establishment difficult. If the original planting fails, a second attempt may require expensive treatments. Within salmonberry associations, riparian fringes, topographically shaded areas, topographic depressions, and areas just downhill from compacted roads and landings are likely to be difficult and expensive to reforest even with good stock and animal damage control.

It appears in retrospect that we may have generalized our reforestation treatments in salmonberry associations in response to some general observations about vegetation development. We now use operational data to focus our concept of the problem, which will allow more site-specific application of treatments. This process will continue to be used in analagous

cases. The combination of operational data analysis and the ability to analyze geographic information at a landscape scale will be a very powerful planning tool in the future.

This approach has also proven useful in refining the plant association classification. This investigation made clear the fact that the salmonberry associations are not homogeneous with respect to tree and shrub growth. Topographic position has an important impact on early seral competitive interactions. The impact is not transient. Early establishment of long-lived conifers shapes community composition and structure for hundreds of years. Future revisions of the plant association classification will include topographic variants of the salmonberry associations. They will follow the form western hemlock/salmonberry (riparian), for example. Other groups of plant associations may contain similar variation which will come to light in the on-going process of application.

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TIMBER LAND CLASSIFICATION SYSTEM AND PROGRAMS
DEVELOPED FROM HABITAT TYPING AND TIMBER STAND PROGNOSIS

Herbert S. Malany

ABSTRACT: Describes a land classification system developed using habitat types and a computer mapping system, stocking guides for precommercial thinning, and the diameter at which a tree is economically sound.

INTRODUCTION

I will be discussing the land classification system and mapping program developed by Boise Cascade Corporation using habitat types (h.t.), the stocking guides for precommercial thinning, and the DBH at which a tree should be harvested.

Before beginning to discuss each of these topics I will define the specific terms we coined for the topic.

For the land classification discussion there are two coined terms I need to explain:

1. "Productivity Class" (PC) is defined as a grouping of h.t.'s that have similar growth potentials.
2. The "Stand" is our smallest land management unit and was defined by overlaying the logging method, the timber type, and the productivity class.

MAPPING PROJECT

In order to build the stand map we originally visualized, three map layers had to be developed. The maps were the h.t., timber type, and logging method.

The first one, the h.t. map, was completed over a 2-year period with a lot of help from Bob Steele. Our first challenge and Bob's was to teach our foresters:

1. To identify the different h.t.'s.
2. To use aerial photos and topographic maps to extend an identified h.t. to map additional areas without on-the-ground observation.

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3. To determine the amount of ground sampling necessary to insure the h.t.'s were extended correctly.

The other two map layers we developed were:

1. Logging Method--The ownership was mapped by logging method or topography. Ground less than 35 percent topographic slope was classified as skidder ground, slopes between 35 percent and 55 percent were called tractor, and all lands over 55 percent were classified as cable or helicopter logging.

2. Timber Type--Standard terms for timber types were used, but we developed definitions to fit our stand structure. For example, to be classified as large sawtimber, the stand had to average 60 square feet of basal area over 20 inches DBH.

The first project after the field mapping was completed was delineating the ownership into stands or management areas based on habitat type, timber type, and logging method.

Our original definition for a stand was to have the h.t. map as the base layer and overlay with the timber type and logging map. With the completion of the h.t. mapping, it was readily apparent the 24 h.t.'s would have divided the ownership into thousands of map islands. Then when the timber type and logging layer were added to the h.t. layer, the number of stands this definition would have identified would have been both astronomical and unmanageable.

While the mapping was going on, the diameter growth coefficients for Prognosis (Stage 1973) were being developed by Chuck Hatch and Al Stage for the major h.t.'s in southwest Idaho to enable Prognosis to predict the growth rates for our geographic and climatic area.

To use Prognosis in southern Idaho, it was necessary to develop statistically sound coefficients for diameter growth for the h.t.'s found in the area. To get enough sample plots, we had to first h.t. the Continuous Forest Inventory (CFI) plots on Boise Cascade's land and then combine the data with diameter growth information from Boise, Challis, and Payette National Forests along with the Idaho Department of Lands. These coefficients became the Central Idaho version of Prognosis.

For height growth, multipliers were developed for Prognosis so the model would predict the actual growth experienced between two measurements from the CFI plots on the Corporation's lands. To test the model, the growth predictions were compared to and adjusted when necessary to the actual diameter and height growth experienced on the different h.t.-timber type combinations from the Corporation's CFI plots.

With the development of the diameter growth coefficients and height multipliers for Prognosis completed, we found when running growth projections for the h.t.'s found on the Corporation's lands, the growth projections fell into four similar groupings. This allowed us to develop the four Productivity Classes and reduce the stand combinations to a manageable number.

The 24 h.t.'s found on the Corporation's lands in southwestern Idaho were grouped in four productivity classes:

1. Wet Grand Fir--These h.t.'s are the best sites on the Corporation's land. Mountain maple is the major associated species.
2. Dry Grand Fir--These are the drier grand fir areas. Grand fir-huckleberry is the major h.t. of this series.
3. Wet Douglas-fir--These h.t.'s are the higher elevations and north slopes on Douglas-fir sites. Ninebark is the major associated species.
4. Dry Douglas-fir--These are the driest sites we have. Pinegrass is the major associated species.

When the h.t.'s were consolidated into the four productivity classes and overlaid with the timber type and logging maps, the stand map for the ownership was developed with a manageable number of stands. With 5 acres the minimum size stand, over 2,000 stands were defined. The stand combinations developed 31 identifiable management types--combinations of logging method, timber type, and productivity class.

With the completion of the development phase of the program, the coefficient for Prognosis and mapping, we began developing other parts for the Timber Management (TM) program.

The first project after mapping was completed was the development of an inventory for each of the stand combinations--tractor ground, small sawtimber, productivity class 3. The data for the inventory were limited to Boise Cascade's plots. The plots were classified by logging type, timber type, and productivity class to develop a yield table for each stand definition. Additional plots were added to stands with insufficient CFI plots for a sample. This information was also used to develop the yield tables for TimberRAM, FORPLAN, and the standing timber inventory.

IMPLEMENTING THE TM PLAN

Now, I will discuss two of the programs we developed to assist in implementing the TM Plan. The first program is the precommercial thinning (PCT) guidelines. The guidelines were developed for each logging method and productivity class and are designed as stocking guides where the minimum merchantable DBH and critical basal area are reached at the same time.

Before continuing, I will explain two terms used in the thinning guides:

1. Minimum Merchantable DBH--The DBH when the selling value for the lumber is great enough to pay for the costs of logging and manufacturing, and provide a normal profit. No value remains for stumpage.
2. Critical Basal Area (CBA)--The maximum basal area for optimum stocking and growth.

To develop the PCT guidelines, it was first necessary to determine the Minimum Merchantable DBH. This is the DBH where the tree generates only enough lumber selling value to pay the logging and manufacturing costs and provide a normal profit to the mill.

After the minimum DBH for each logging method was determined, the stocking levels needed to optimize growth per tree and per acre were developed for each productivity class. We found that the long-term growth predictions and the CBA for each of the Grand Fir Productivity Classes and the Douglas-fir Productivity Classes were similar, so they were consolidated into two PCT guidelines.

By not harvesting below the minimum basal area, the leave stand is left stocked and growing at the maximum rate until the next entry.

The CBA's for the guidelines were determined by looking at three growth responses in Prognosis. The responses were the number of years after thinning before:

1. The reduction in basal area growth occurs.
2. The incremental cubic growth starts to decline.
3. A reduction in net cubic growth occurs.

The study was made using hypothetical stands of pure Douglas-fir (DF), ponderosa pine (PP), and grand fir (GF) thinned to 40, 60, 90, 120 and 150 square feet of basal area for each PC and then growing the stands in Prognosis for 10-year increments.

Prognosis runs were made to determine basal area when:

1. The stands were projected over time to determine the basal area at which the growth rate starts to decrease due to mortality. This exercise is helpful in determining the maximum basal area a stand can carry. However, it does not give the point at which stand volume growth is maximized (fig. 1).

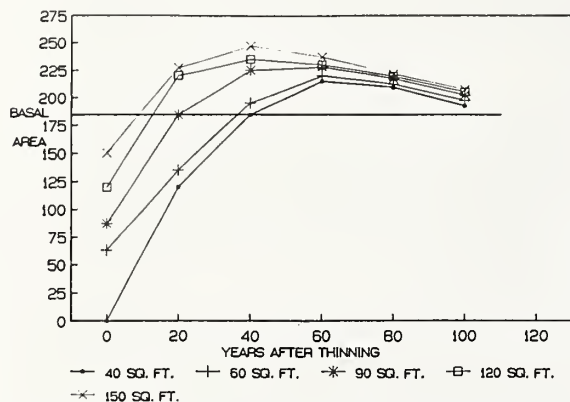


Figure 1--Reduction in basal area growth for five initial thinning densities.

2. Incremental growth is defined as total growth per period less mortality. The growth was determined by dividing the new growth for each period by 10 to determine the annual cubic foot growth for each period. This exercise shows the period at which growth is at the maximum (fig. 2).

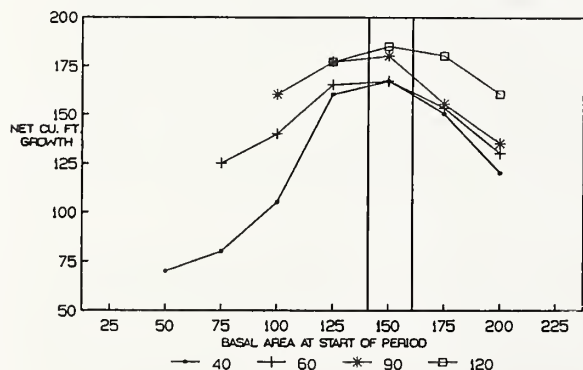


Figure 2--Reduction in incremental cubic foot growth.

3. This calculation is done by totaling the net growth to date and dividing by the corresponding years to determine when the net growth starts to decline. This calculation determines the Critical Basal Area or the density at which the cumulative growth rate declines (fig. 3).

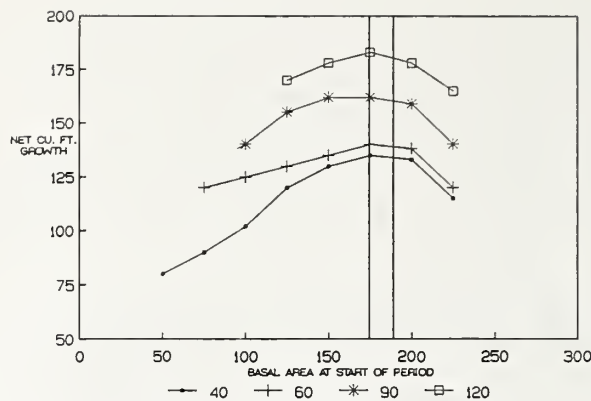


Figure 3--Reduction in average cubic foot growth.

The reduction in average growth generally occurred 20 sq. ft. higher than the reduction in incremental net growth. This indicates that while the incremental growth is declining the stand continues to grow faster than average for a period of time. We decided to use the period when the reduction in net cubic growth occurs to determine the Critical Basal Area because the trees would be larger and more valuable.

After the minimum DBH and Critical Basal Area were determined, the stocking level for each logging type was an easy calculation based on the minimum merchantable DBH, annual basal area growth, years to next entry, and the Critical Basal Area.

The Critical Basal Area and the minimum basal area from the PCT study were used in the development of our marking guides.

TARGET DBH

The last study I will discuss is the development of the "Target DBH".

The definition for the Target DBH is the DBH where the interest rate the tree is returning stops decreasing. This is the diameter at which a tree should be harvested unless it is needed for silviculture purposes.

To arrive at the Target DBH Growth, the average crown ratio and height for the dominant and co-dominant trees were calculated for PP, DF and GF by diameter class and PC using data from the CFI plots. The data sets were run in Prognosis to determine the number of years it takes a tree to increase 1 inch in diameter (fig. 4).

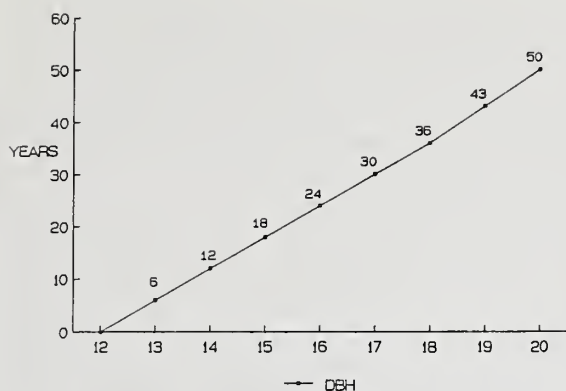


Figure 4--Target DBH growth.

Then the average tree size and the piece size for each diameter class and species were developed from Prognosis. The piece size information was used to determine the logging cost, which was subtracted from a log purchase price to determine the stumpage value for each DBH class (fig. 5).

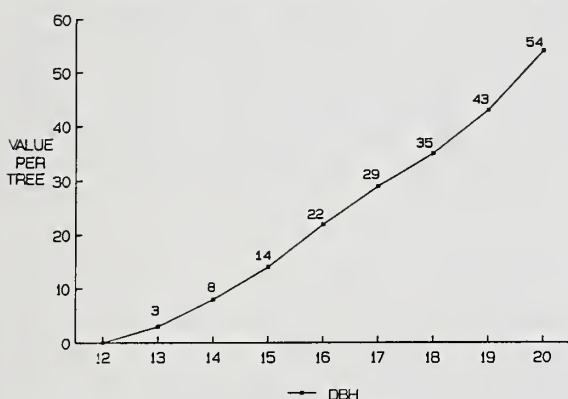


Figure 5--Stumpage value by DBH.

A periodic annual percent of return was calculated by species and logging type. The periodic return shows the diameter at which the annual percent of return in value tends to level out. The percent of interest is based on the tree value at the beginning DBH, the time required to grow to the next larger DBH, and the tree value at the larger (ending) DBH (fig. 6).

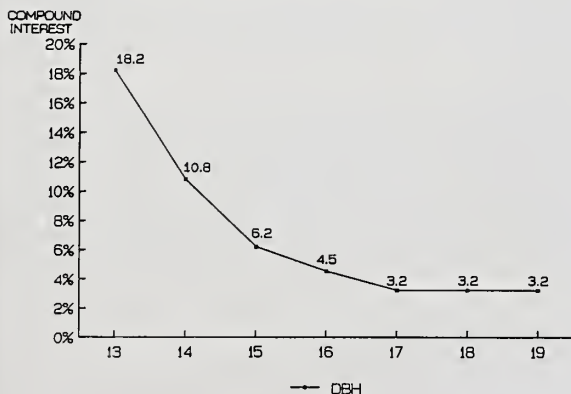


Figure 6--Periodic annual percentage return by tree.

Finally, a cumulative annual interest rate was calculated by species and logging type for each DBH (fig. 7). This percentage is based on total tree age, with a \$.01 value at age zero, and the assumption that trees reach 12 inches DBH at age 60 on PC 1. This calculation shows the cumulative annual return by diameter class and the DBH at which the accumulative compounding interest rate stops declining.

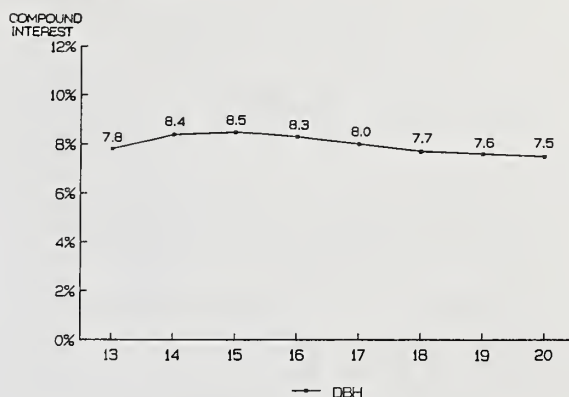


Figure 7--Cumulative annual percentage return on tree value by DBH.

The periodic and cumulative interest rates tended to level out at 17 or 18 inches DBH for all species and logging types, thus determining the target DBH.

LONG-TERM EFFECTS

Briefly, another project using h.t.'s and Prognosis was to determine the long-term effects of various silvicultural treatments. We made various studies with TimberRAM and FORPLAN to determine the best treatment alternatives for our stands. Clearcutting vs. seed tree vs. shelterwood vs. selective cutting were compared against each other to determine the most cost-effective way to manage the forest.

The conclusion was to stay with the selective systems whenever possible, that a limited amount of clearcutting and planting was necessary in some stand types, and the PCT thinning was desirable in a limited number of stands.

CONCLUSIONS

In conclusion, after all the harvesting, data gathering, Prognosis runs, studies, and observing the results of a mixture of silviculture treatments over the last 20 years in the ponderosa pine-mixed conifer forests of southwestern Idaho, I think:

1. Foresters are in much too big a hurry to reach that "managed stand in the sky" today by attempting to convert a 70- to 200-year old wild stand to an idealistic managed stand in one entry. On the silviculture side of the ledger, the result is overcutting on the initial entry with the

associated problems--excessive logging damage to the leave stand caused by the heavy cut, sunscald, blowdown, brush invasion, and damage to the watershed and big game habitat. On the political side is disapproval of the results by the public and other specialists and credibility about our ability to manage forests. On the economic side of the ledger, the owner is faced with a triple jeopardy of:

- A. Paying a higher logging cost to harvest sub-economic trees (thrifty growing stock with a DBH of 16 inches or less).
- B. Receiving lower stumpage from the mill because the logs are smaller and lower in value.
- C. Waiting longer for the next economic return because the next entry (the 10- to 16-inch trees) were harvested today.

2. The foresters are not taught to manage the total forest, only to manage individual stands. The stand receiving the treatment is silvicultured to death. Subeconomic thrifty growing stock, which is included in the allowable harvest volume, is cut to arrive at the "managed stand in the sky." Then valuable high-risk or diseased trees in the next stand are left to die.

3. That foresters are too impatient to wait for natural regeneration to occur. They rush to plant areas without allowing time for natural regeneration to become established. Stands in the pine and mixed conifer types will regenerate naturally when the basal area is 70 sq. ft. or less and thrifty seed trees remain.

The best silviculture prescriptions are the ones that yield the highest return to the landowner today and minimize post-harvest silviculture prescriptions to treatments that are truly cost effective or are needed to control insects and diseases. In the stands of southwestern Idaho, this is easily accomplished by using common sense and prescribing practices that remove the larger diameter, economically mature trees, leaving the thrifty 10- to 16-inch trees for future harvests.

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BIOGEOCLIMATIC CLASSIFICATION--THE SYSTEM AND ITS APPLICATION

Del Meidinger and Andy MacKinnon

ABSTRACT: Resource managers in British Columbia commonly use a system of ecological classification called the Biogeoclimatic Classification (BGC) system. The system has been further developed and implemented by the B.C. Forest Service over the last 10 years; most of the province has now been classified. The BGC system is a hierarchical classification system with three levels of integration: local (vegetation and site classifications); regional (zonal or climatic classification); and chronological. Foresters primarily use the units of the regional (biogeoclimatic units: zone, subzone variant) and local (site units: site association, site series, site type) levels. Soil moisture and nutrient regimes are used to classify site units within biogeoclimatic units, using maps and field guides developed in each Forest Region. Interpretations provided for site units assist foresters in developing management prescriptions.

INTRODUCTION

Ecosystem classification in British Columbia follows the biogeoclimatic system. The classification provides foresters and other resource managers with a common framework for ecological management of forests and rangelands. Over the past decade, the classification system has become firmly entrenched in forest management and is used as well by wildlife, range, and parks managers. This paper will deal primarily with the use of the system in forest management.

Ecosystem studies carried out from 1950-1975 by Dr. V.J. Krajina and his students at the

Paper presented at the symposium, "Land Classifications Based on Vegetation: Applications for Resource Management", Moscow, ID, November 17-19, 1987.

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University of British Columbia resulted in the development of the Biogeoclimatic Classification (BGC) system (e.g., Beil and others 1976; Krajina 1965). The Forest Service adopted this system in 1975 and embarked on a province-wide program to produce an ecosystem classification that could be used at an operational scale. Many modifications to Krajina's system have been made over the years (Pojar 1983) - the most recent account of the system is provided by Pojar and others (1987) and is summarized here.

The classification of British Columbia has proved an immense undertaking for a number of reasons. The province of B.C. consists of about 30 million hectares dissected by a series of northwest-southeast trending mountain ranges; much of the area is inaccessible except by helicopter. The landbase is divided for management purposes into six Forest Regions. Ecosystem studies have been carried out primarily by research staff in the six Forest Regions with some provincial coordination. To date approximately 250 man-years have been invested in the project. Most of the sampling has been completed and operational maps and reports are available for most of the province. These maps and reports are presently in use by a broad spectrum of resource managers as information sources and as aids to decision-making.

Regional classifications are presently being correlated to produce a truly provincial classification. The data are being analyzed from a broader perspective with the result that many classification units are being merged--very similar ecosystems in different Forest Regions will have the same name, code, and interpretations. The results of this provincial correlation will become operationally apparent over the next few years.

PRINCIPLES OF BIOGEOCLIMATIC CLASSIFICATION

The BGC system organizes ecosystems at three levels of integration - local, regional, and chronological - with the intention of showing the relationships among ecosystems in form, space, and time. The local level organizes ecosystems according to their similarities in form, i.e., the structure and composition of their vegetation and physical environment. This

is done by vegetation and site classifications (fig. 1) resulting in vegetation and site units. At the regional level, the vegetation on "zonal" sites is used to infer the regional climate; this zonal or climatic classification defines biogeoclimatic units. The chronological level is used to organize ecosystems according to site-specific chronosequences by arranging the vegetation units recognized for a particular site unit according to site history and successional status.

For practical purposes, a forester need only be concerned with the zonal and site classifications; the vegetation classification, however, is integral to developing both of these. Vegetation is emphasized because it is considered to be the best integrator of the combined influence of a variety of environmental factors affecting the site, and because differentiating floristic criteria can be determined. Vegetation units are floristically uniform classes of plant communities in the sense of the Braun-Blanquet approach (Westhoff and van der Maarel 1980). They are arranged in a phytosociological hierarchy where the plant association is the basic unit; alliances, orders, and classes are groups of associations, and subassociations are divisions of an association (table 1). To facilitate both classification and indication of environment, the Braun-Blanquet approach uses species with relatively narrow ecological amplitudes. Such species are 'diagnostic'; a group of them constitute a

'diagnostic combination of species' (DCS). The DCS is exclusive to a given vegetation unit and therefore is used as the sole differentia at the vegetation level. The DCS usually requires at least one differential-species (see table 1 and Pojar and others 1987). Determination of diagnostic values and combinations of species involves tabular comparisons and the criteria of table 1; see Pojar and others (1987) for examples.

In B.C., the vegetation classification is presently being developed for late seral to climax ecosystems and is being used to correlate the classifications of the different Forest Regions. As early seral vegetation is sampled, it too will be classified and then organized, using the site classification, into site-specific chronosequences.

Biogeoclimatic units are the result of zonal (climatic) classification and represent classes of ecosystems under the influence of the same regional climate. Again, there is a hierarchy of units, with the biogeoclimatic subzone as the basic unit (table 1). A subzone is recognized as having a distinct climax (or near-climax) plant association on "zonal" sites. Zonal sites are intermediate in moisture and nutrients and are considered to reflect the influence of climate more strongly than other sites (e.g., Sukachev and Dylis 1964); therefore, they are the best reference sites to compare climate using climax vegetation. Subzones are grouped into zones and divided into variants.

The Sub-Boreal Spruce (SBS) zone, for example, represents an area of about 170,000 km² in central British Columbia, characterized by a continental climate with seasonal extremes of temperature, relatively short summers, and relatively low annual precipitation (Meidinger and Pojar 1983). Zonal sites within the SBS are characterized by climax forests of hybrid white spruce (*Picea engelmannii* X *P. glauca*), often in combination with subalpine fir (*Abies lasiocarpa*). Within the SBS zone, more regional climatic differences are evident: for instance, total annual precipitation ranges from 472 mm in the rainshadow of the Coast Mountains to 1233 mm in the foothills of the Rocky Mountains (McLeod and Meidinger 1986). These climatic differences are reflected in the development of different zonal, or climatic, ecosystems on zonal sites. Biogeoclimatic zones are divided into subzones based on the geographical extent of a particular zonal ecosystem. For example, on zonal sites in the relatively dry SBS_e subzone, the climax plant community has a canopy of lodgepole pine (*Pinus contorta* var. *latifolia*) and hybrid white spruce, a shrub layer dominated by black huckleberry (*Vaccinium membranaceum*), and a herb layer characterized by bunchberry (*Cornus canadensis*). The zonal ecosystem of the moister SBS_j subzone has more hybrid white spruce and subalpine fir in the canopy, black twinberry (*Lonicera involucrata*) in the shrub layer, and the excellent moist site indicator species, oak fern (*Gymnocarpium dryopteris*), in the herb layer;

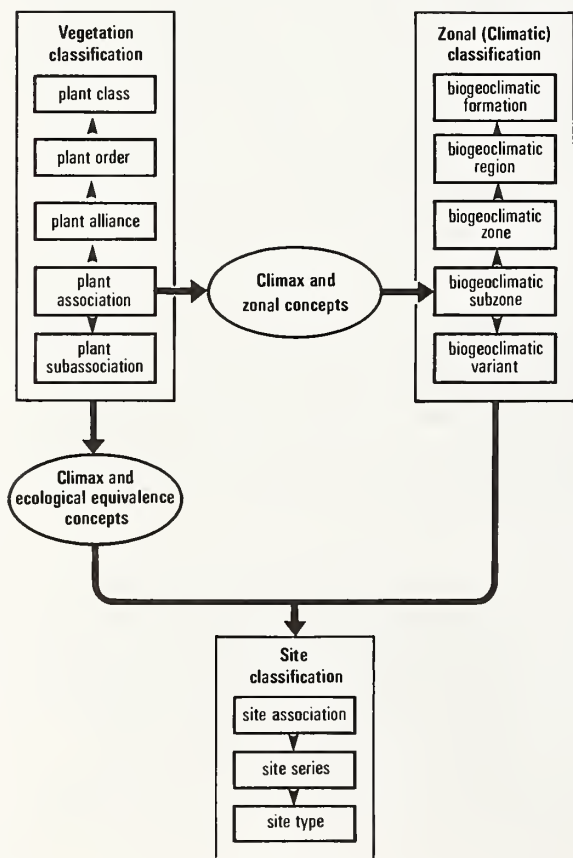


Figure 1--Categories and relationships of vegetation, zonal, and site classifications.

the very wet SBSf subzone features the wet site indicator, devil's club (*Oplopanax horridum*), as the predominant shrub on its zonal sites. Sub-zones can be further divided into variants, based on finer differences in regional climate; the SBSe has been divided into western (SBSe1) and eastern (SBSe2) variants. The name "SBSe2" thus

denotes the Sub-Boreal Spruce Zone (SBS), Moist Cool Central Subzone (e), Fraser Basin Variant (2).

Site units represent groups of sites (or ecosystems), regardless of present vegetation, that have the same, or equivalent, environmental properties and potential vegetation. The basic

Table 1--Synopsis of levels and categories of biogeoclimatic classification

Category	Differentia	Example
Vegetation classification		
Class	exclusive DCS ¹	<u>Picea glauca x engelmannii</u>
Order	exclusive DCS	<u>Picea-Vaccinium</u>
Alliance	exclusive DCS	<u>Picea-Vaccinium</u>
Association	exclusive DCS	<u>Picea-Vaccinium-Viburnum</u>
Subassociation	exclusive DCS or non-exclusive DCS with 2 or more species	<u>Picea-Vaccinium-Viburnum</u> , <u>Rubus(parviflorus)</u>
Zonal classification		
Formation	climatic group (Koppen/Trewartha)	Microthermal Coniferous Forest
Region	climatic type (Koppen/Trewartha); DCS derived from zonal and non-zonal climax ecosystems	Canadian Boreal Forest
Zone	zonal plant order (DCS derived from zonal climax ecosystems)	Sub-Boreal Spruce (SBS)
Subzone	zonal plant association (DCS derived from zonal climax ecosystems)	Moist Cool Central SBS (SBSe)
Variant	zonal plant subassociation (exclusive or non-exclusive DCS derived from zonal climax ecosystems)	Fraser Basin SBSe (SBSe2)
Site classification		
Association	range of biogeoclimatic subzones or variants, soil moisture regimes, soil nutrient regimes, and if appropriate, an additional environmental factor or property controlling vegetation of the parent plant association	<u>Picea-Vaccinium-Viburnum</u>
Series	biogeoclimatic subzone or variant	SBSe2: <u>Picea-Vaccinium-Viburnum</u>
Type	one or more factors or properties that are identified as the major source of edaphic variation within the site association	SBSe2: <u>Picea-Vaccinium-Viburnum</u> / Sandy

¹DCS = diagnostic combination of species; must include at least one differential- or dominant differential-species.

Differential (d): species that is clearly associated with more than one unit in a hierarchy; presence class \geq III and at least two presence classes greater than in other units of the same category and circumscription.

Dominant differential (dd): species that does not meet the presence criteria above but shows clear dominance in more than one unit in a hierarchy; presence class \geq III, mean species significance \geq 5 and two or more significance classes greater than in other units of the same category and circumscription.

Presence classes as percent of frequency: I=0-20, II=21-40, III=41-60, IV=61-80, V=81-100.
Species significance classes and percent cover: +=0.1-0.3, 1=0.4-1.0, 2=1.1-2.2, 3=2.3-5.0, 4=5.1-10.0, 5=10.1-20.0, 6=20.1-33.0, 7=33.1-50.0, 8=50.1-75.0, 9=75.1-100.

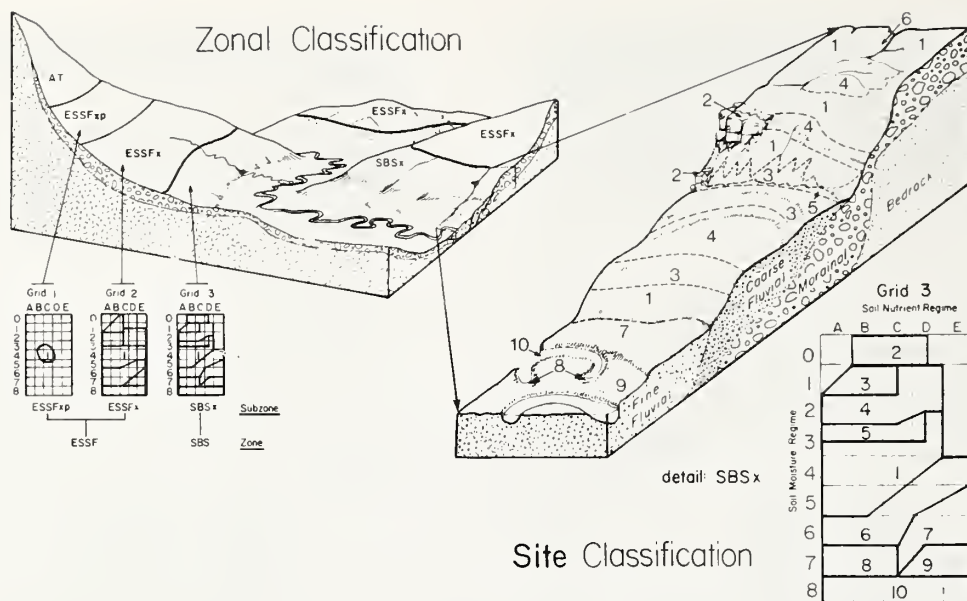


Figure 2--Schematic relationships between zonal and site classifications. AT, ESSF, and SBS are abbreviations for the Alpine Tundra, Engelmann Spruce - Subalpine Fir, and Sub-Boreal Spruce zones, respectively.

category in site classification is the site association; series and types are divisions of associations (table 1). The site association is equivalent to the habitat type (Daubenmire 1968). The limits of a site association are the same as those of the parent plant association - in other words, all land areas capable of producing vegetation belonging to the same plant association at climax are included in a single site association. The vegetation potential of a site association can be described in terms of all seral and the climax plant community that may occur on the site. The site association is characterized, however, by a combination of climate, soil moisture and nutrient regime, and, if appropriate, by an additional environmental factor or property strongly influencing the development of the parent plant association. For example, two site associations may occur in the same climate, and on sites with the same range of soil moisture and nutrient regime, but one may be subject to periodic flooding, and the other to temporary seepage, resulting in two different floristic assemblages distinguishable as plant associations.

A site association may contain ecosystems from several different climates and so be quite variable in actual site conditions. Dividing the association into site series produces site units that are climatically, and therefore usually edaphically, more uniform and more predictable in their response to management. A site series is equivalent to the ecosystem association of previous accounts (e.g., Pojar 1983).

Site series are then partitioned into site types according to one or more (usually many) edaphic properties thought to affect ecosystem response

to management. This produces the most edaphically consistent classes of ecosystems. Site types reflect the compensating effects of site conditions within a uniform climate in producing similar vegetation. Site types represent ecosystem units that are uniform in the largest number of environmental characteristics.

The site association is named after the parent plant association (table 1). Site series are named by prefixing the name of the site association with the symbol for the biogeoclimatic subzone or variant; the site type consists of the name of the site series modified by one of the soil and landform characteristics.

SITE IDENTIFICATION

Figure 2 displays the relationship between the zonal and site classifications on a segment of a hypothetical landscape. One of the most important aspects of applying a site classification is correct identification of the classification units. Sites can be mapped, but province-wide mapping at an operational scale (i.e., 1:2,000 - 20,000) is not feasible. Instead, a variety of tools are provided to assist in identification of site units in the field. Users are provided with small-scale biogeoclimatic maps, keys, descriptive tables of characteristic understory vegetation and environmental features, slope position diagrams, edatopic grids, and guides to plant identification. Forest management interpretations accompanying each unit are used to develop a site prescription.

The first step in site identification is determining the biogeoclimatic unit. Biogeoclimatic maps at scales of 1:100,000 to 1:600,000,

depending on the area, are available for the entire province (e.g., McLeod and Meidinger 1986; Nuszdorfer and others 1985). In areas near map boundaries, it is prudent to confirm the biogeoclimatic unit by checking certain habitat and floristic features with tables of information provided in the appropriate classification manual. These may be general features of the subzone or variant, or specific features of the zonal ecosystems.

Classification reports or handbooks are used to identify the site units in each subzone or variant. The organization of these guides, and the information presented, depends on the preference of the authors. All reports, though, contain an edatopic grid for each biogeoclimatic unit. The edatopic grid (fig. 3) displays the site units over a grid of relative (within the subzone or variant) soil moisture and nutrient regime classes. Soil moisture and nutrient regimes (Pojar and others 1987) can be determined using keys or tables (e.g., Green and others 1984; Lewis and others 1986) by assessing certain environmental features.

Soil and site factors used to determine soil moisture and nutrient regime include slope position, slope gradient and aspect, soil texture and coarse fragments, humus form and depth, organic matter content, depth to water table, presence of mottling, rooting depth, and parent materials. These factors have been selected as

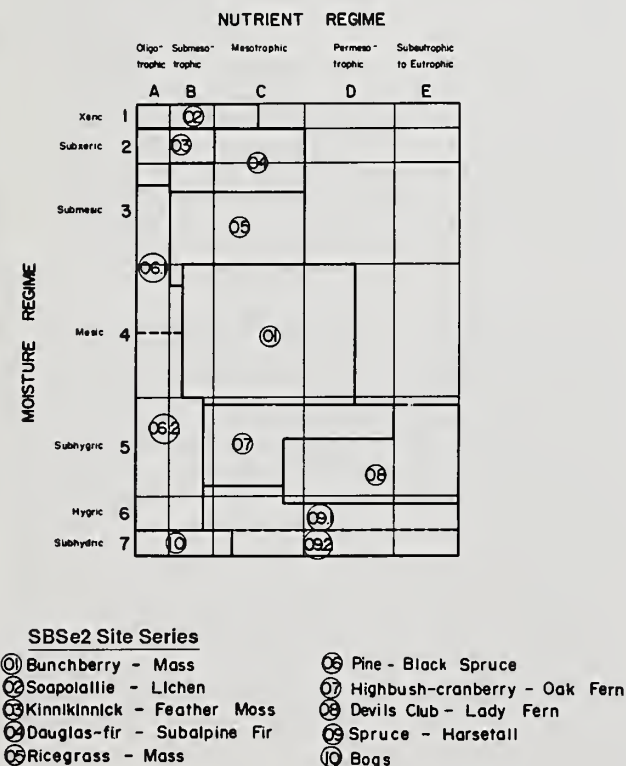
having the greatest influence on, or relation to, soil moisture and nutrient regime, and they can be assessed quickly and accurately with moderate training.

Presence and abundance (percent cover) of the plant species present on each ecosystem are noted and compared to the lists given for each site unit. Though vegetation is an extremely useful indicator of site conditions in mature forests, caution must be exercised in assessing more disturbed sites.

After assessing moisture and nutrient regimes, a site unit is determined from the grid and then confirmed by using keys to the site units, descriptive tables of characteristic understory vegetation and environmental features, and/or slope position diagrams. Keys utilize both vegetation and site features (e.g., Cariboo Forest Region 1987; DeLong and others 1987; Klinka and Krajina 1986; Lewis and others 1986).

Descriptive tables may be brief and limited to one or two pages per biogeoclimatic unit (e.g., Cariboo Forest Region 1987; Lloyd 1984) or more detailed and consisting of one page per site unit (e.g., Houseknecht and others 1986; MacKinnon and McLeod 1986). Slope position diagrams are often used to depict the location of the site units on the landscape in relation to slope position, aspect, and parent material (e.g., Mitchell and others 1981; Utzig and others 1986).

Site (ecosystem) units are given a symbol to allow for coding into databases. The symbol for a site series is appended after the biogeoclimatic code and separated by a slash; SBS2/01 is a site series in the SBS2 variant.



To illustrate the process of site identification in the BGC system, consider the SBS2 variant. A user would first consult the appropriate 1:250,000 biogeoclimatic unit map, from which it could be determined that the area to be classified lies in the SBS2. The user would then take the appropriate field guide (DeLong and others 1987) to the site to be classified. After noting various environmental and vegetational characteristics, the user would turn to the edatopic grid for the SBS2 (fig. 3). Ten site series within the SBS2 are displayed on the grid; by choosing the appropriate moisture regime (y-axis) and nutrient regime (x-axis) one arrives at the number of a site series. If the moisture and nutrient regimes were both judged to be average (mesic, mesotrophic), the grid would indicate the SBS2/01 site series. The user can then turn to a description of the site series (fig. 4) to confirm or reject the identification. The field guide also presents other aids to site unit identification, including keys and slope position diagrams.

Figure 3--Edatopic grid of ecological moisture and nutrient regime for the SBS2 variant.

BUNCHBERRY - MOSS

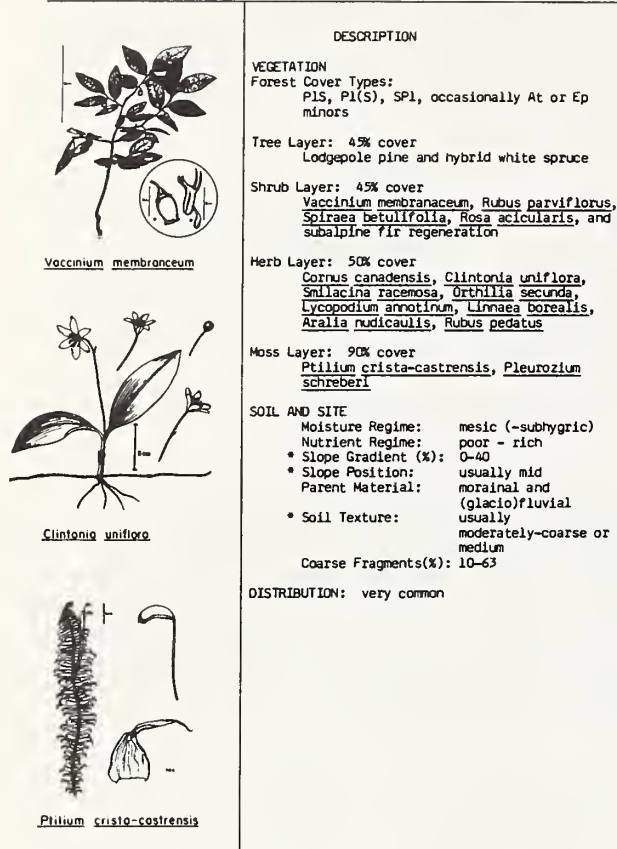


Figure 4--Description of the SBS2/01 site series.

SITE INTERPRETATION

The BGC system provides a framework for presenting interpretations for forest management that suggest treatments most suited to a particular group of ecosystems. The interpretations are based on an understanding of the structure and function of the ecosystems, limiting factors, constraints, capabilities, accumulated knowledge of the reaction of a particular site unit to proposed manipulations, and social (ethical) objectives such as maintaining site productivity or sustained yield.

Interpretations are determined for the conceptualized ecosystems, and they include limited management objectives and economic considerations. Prescriptions, on the other hand, are developed using the interpretations (Lewis 1987); they are specific to an individual site and stand, and they are determined after consideration of many management and economic factors.

Interpretations are primarily for silviculture and include tree species selection, site preparation, regeneration method, stocking standards and stand tending considerations, among others (e.g., Cariboo Forest Region 1987; Green and others 1985; DeLong and others 1987; Lewis 1987, and others 1986; Mitchell and others 1981; Utzig and others 1986). Engineering and range management interpretations are also made (e.g., Cariboo Forest Region 1987; Comeau and others 1982).

Two approaches have been taken to the presentation of these interpretations: multiple interpretations for a classification unit; and single interpretations for groupings of related classification units. Both approaches are valid and the utility of one over the other depends on the needs of the specific user group applying the interpretations.

To continue our previous example, forestry interpretations for the SBS2/01 site series are presented in figure 5. After determining that the unit in the field is the SBS2/01 site series, the user can then turn to the interpretations for that site unit for assistance in formulating a prescription for the site. In this case, it is suggested that the site be harvested by clearcutting; that site preparation consist of a light broadcast burn or drag scarification; that regeneration options include planting lodgepole pine or hybrid white spruce, or encouraging natural seeding in of lodgepole pine; that aspen suckering and mistletoe have been problems on this site series in the past; and that site productivity should allow production of spruce or pine sawlogs on a 70-year rotation.

Identification of the ecosystems comprising a proposed or treated block is required for all silviculture assessments on Crown forest land (Green 1985). Through the pre-harvest silviculture prescription process, the ecological characteristics of a block must be assessed, and all stages from harvesting to the free growing stand prescribed for component sites within a block.

SILVICULTURE INTERPRETATIONS

Logging Method	Brush Hazard	Other Constraints	Site Preparation	Species Select	Regen. Delay	Time to Free Growing	% Canopy Removed	Regeneration Options							Stand Tending	
								Natural		Artificial					Time of Thinning	Stems/ha after Thinning
clearcut	mod.	-mistletoe	-light drag scarify -mix humus with mineral soil or light broadcast burn (remove L horizon) -windrow & burn	P1 Sx	3 1	5 5		P1	Seeding /ha 1500	P1 Sx	Shoot/Root Ratio 2.5/1 2/1	Caliber (mm) 4 5	Height (cm) 15 22	Seeding /ha 1500 1000	15	1000

TIMBER INTERPRETATIONS

Logging Method	Slope %	Seasonal Constraints	Recommended Harvesting System
clearcut	0-30 31-40	S or W S or W	conventional medium cat

II. Silviculture Applications:

- do not accept advance B1 regeneration.
- conduct a P1 cone survey to see if enough seed is present to establish a natural P1 stand. If so, mechanically treat site.
- if cones are insufficient, plant P1 stock without site preparation.
- light drag scarify if logged in winter and cone crop survey indicates a good supply of seeds.
- windrow and burn if stand has 60% + component of Sx.
- thinning of over-dense P1 will need to be done only if a site inspection indicates the need for this treatment.

III. Silviculture Problems:

- aspen suckering can be a serious problem.
- mistletoe infestation may be high on these sites so a mistletoe clause should be written into the cutting permit to help reduce the impact of the disease on the future stand.

COMMENTS

I. Management Objectives:

- manage for sawlog on a 70 year rotation.

Figure 5--Forestry interpretations for the SBS2/01 site series.

SUMMARY

Biogeoclimatic classification has been applied to a region of North America that has complex patterns of climate, topography, geology, physiographic history, soils and vegetation. The system has been implemented by the British Columbia Forest Service, and many resource managers now use the system. The BGC system is a hierarchical classification with three levels of integration -- the local, regional, and chronological. The zonal classification is at the regional level, the vegetation and site classifications at the local level. The chronological level of classification is developed by applying the vegetation classification to seral eco-systems and organizing the associations within the site classification (Pojar and others 1987).

A variety of tools are provided to assist foresters in identifying the site units and in developing their forest management prescriptions. The application of the system has resulted in an increased ecological awareness among practicing foresters and in improved forest management practices. Results of operational trials and research can be extrapolated to other areas more successfully within the framework provided by the classification. The opportunity now exists for foresters in British Columbia to practice forestry as "applied ecology".

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TOWARD A USER-FRIENDLY ECOSYSTEM: MYTH OR MIRTH?

Edward F. Schlatterer

ABSTRACT: Classifications of vegetation are not yet refined enough by other environmental factors to adequately identify a usable potential. In most cases ecotones, alternative successional pathways, and early successional development have not been identified adequately enough to satisfy the needs of the users. Some of the traditional concepts of succession need to be reevaluated to adequately identify factors and mechanisms that contribute to the arrest of seral stages for long indeterminable periods, or to the development of new potentials. Classifications must be modified to satisfy the needs of the user for short-term predictions in early succession that can be used to make rational management decisions and minimize the risk of making wrong decisions.

INTRODUCTION

I am John Q. User. I am a resource manager. I deal with existing vegetation.

- Much of it is severely disturbed.
- Much of it has been disturbed over a long period of time by multiple disturbances.
- Some disturbances are long-term and some are short-term.
- Some disturbances are intermittent and some are continuous.
- Some disturbances are slight while others are severe.
- Exotic species are present in the vegetation.

I also deal with the land.

- Much of the soil, on the lands I deal with, has been disturbed.
- On much of the lands I deal with, soil has been lost.

I have some problems:

1. I need to be able to predict what the consequences are of managing the land and its vegetation in different ways. I need to know what the

consequences will be next year, 5 years from now, 10 years from now, and 50 years from now.

2. I need to know the consequences of managing the land and its vegetation on every acre.

3. I need to know the consequences of managing the land and its vegetation for all the resources and users.

4. I need to know the risk of making a wrong decision, and the potential consequences of any wrong decision, in advance, so that I can display the degree of uncertainty of my decisions.

Now, here comes Jim Dan D. Classifier. He claims to have a solution to my problem. His solution is:

1. Use his key which contains the species and community characteristics to identify the potential and the characteristics of that potential he has described.

2. Use his classification to identify the potential natural vegetation on my sites and my problems will be over.

Sounds good, I will do it! At my next inventory plot I gather my inventory data as usual--land, soil, and vegetation characteristics. I take my vegetation data, and attempt to use Jim Dan D. Classifier's key and description.

Results:

1. The key leads me to two or more solutions as to what the potential might be.

2. The site of my inventory plot no longer contains an "A" horizon and part of the "B" horizon is missing.

3. My plot contains exotic species not included in the classification.

4. I do not know the nature and duration of the disturbances to the site.

5. I do not know the risk of making the wrong choice and misidentifying the potential.

6. The potential identified by Jim Dan D. Classifier could not possibly occur on my site in less than 100 years.

I am John Q. User, and I still have a problem!
WHAT WENT WRONG?

Paper presented at the Symposium on Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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NEW DIRECTION

I would like to explore with you some directions we need to take to solve John Q. User's problems and make classifications more user friendly and more responsive to user needs.

All too often classifications are developed as an academic exercise with no particular user in mind, with the result that the classification is less than useful and sits on a shelf. Even when the classification is developed for a client, it fails to fulfill expectations. It cannot be systematically fitted in existing inventories, nor can it be applied to existing data, and it does not provide information needed for shorter periods than those necessary to reach potential or near potential. And, for all the reasons stated above for John Q. User, it fails to satisfy the need.

In a few instances, the Jim Dan D. Classifiers have been making serious attempts to satisfy the needs, but in all too many cases they have not. It is, in my opinion, a major failing that must be corrected if we expect to get a lot of good work into practical use. It is imperative that work be initiated in this area if we are to avoid criticism in implementing our Forest plans.

In the 9th Circuit Court of Appeals decision on water rights, the judge ruled that the Forest Service must be able to guarantee, in advance, that State Water Quality Standards will be met. It was not good enough that the procedures used complied with standards for best management practices that were previously established. In my opinion, this same kind of scrutiny and guarantee will be required for all management prescription whether they are water related or not. We will be required to predict in advance consequences of all our management actions, prove that long-term productivity will not be impaired, and most important, provide a measure of how confident we are in our predictions.

As an alternative to proving in advance that impairment will not result, or making a wrong choice, I believe we will be required to define the level of risk involved in each alternative and justify our decision if an alternative other than the lowest risk alternative is chosen.

In order to provide this kind of information, the Jim Dan D. Classifiers are going to have to provide more short-term information, more early successional information, and more information on alternative successional pathways together with the documentation the John Q. Users can use, understand, and display in a meaningful way. They are going to have to provide guidance for sites that occur in ecotones, for handling exotic species, for sites from which soil has been lost, for dealing with different geologic materials, for dealing with different soils or slope steepness or aspect.

In short, the job has just begun when a classification is produced. It is not the end, it is the beginning. It is a new beginning for Jim Dan D. Classifier. It is a challenge that must be taken up if vegetation classification is ever to take a

meaningful place in land classification and management and be used as it should be, as a predictive tool. It is a challenge that must be met in an interdisciplinary fashion.

MULTIPLE COMPONENT NEEDS

Those of you who hold that the vegetation can be used as universal prediction tool, without input from other specialists, need to reassess your position and look at the reality of the current situation. Even the best classification used on landscapes with mostly potential or near potential vegetation can only successfully classify 60 or 70 percent of the landscape. It is only when other factors such as soils, geology, topography, slope, and aspect are incorporated (the exceptions if you will) that John Q. User can successfully classify all of his area. John Q. User has no other option, but to do something with the 30 or 40 percent of his area that he can't classify.

Data related to treatment response can only be successfully extrapolated to other like ecosystems. If the data that define the ecosystem are only based on a single component such as vegetation, they can only be successfully applied to other areas with the same vegetation potential and the same soil, geology, topography, slope, and aspect. Applying data from plots identified by one component, such as vegetation, can only lead to misapplication of results when applied to another site with different soils, geology, topography, slope, and aspect. Land capability identified by one component only, a single resource inventory, will be limited to that one component. Only when integrated components are identified, can a proper extrapolation be made. Integration of components is essential for John Q. User to have the answers for the complex management situations he encounters.

I would like to illustrate what I am talking about, "The dilemmas of the John Q. User's," and in particular the Forest Service John Q. User, in attempting to implement a Forest Plan prescription on a given area of ground.

The Forest Plan identifies a desired future condition of the Forest 50 years into the future. The implementation schedule usually deals with the first 10-year increment. John Q. User needs to know how much of what he is going to do this year, next year, and the year after, is contributing to that desired future Forest condition. He needs to know it with a comfortable degree of certainty.

There were certain basic assumptions that were made in the Forest Planning process. He needs to verify if they were correct or not. He must be certain that his project is consistent with the basic assumption over both the short term and the long term. How many of the classifications for vegetation that you have looked at lately provide this kind of information? Not many, if you have been looking at the same ones that I have recently. They are going to have to provide this kind of information in the future.

PROBLEMS

There are four basic problems that need to be addressed. First, there is a real problem of alternative successional pathways. There is a second problem of alteration of the potential as a result of a disturbance or application of a management prescription. Third, there is the problem of long-term arrest of succession in some stage of succession, other than potential. And fourth, there is the problem of multiple potentials within an identified plant association or habitat type. I would like to briefly address each of these problems.

Successional Pathway

Dr. Ben Norton of Utah State University wrote a rather interesting paper in 1981 for the National Academy of Sciences Symposium on Impacts of Grazing Intensity and Specialized Grazing Systems on Use and Values of Rangelands. Unfortunately, his paper was not included when the report was published in 1984. In his paper, Dr. Norton advanced an alternative model to the traditional rangeland model that has been used to display succession and condition on rangelands. It also has application to forest ecosystems.

Figure 1 is a redraft of a schematic diagram presented by Dr. Norton based on previous studies by others in South Africa with a few embellishments. The traditional view is that

succession or retrogression of vegetation on rangelands follows the right-hand part of the diagram. This part of the graph... "relies on the validity of Clementsian succession, which assumes a kind of "relay floristics" in which successive communities are predictable from the microhabitat generated by their predecessors."

Alteration of Potential

There are many other ecologists who recognize alternative pathways of vegetation change. The reasons for alternative pathways are many, including variations in species occurrence from site to site, the age structure of the plant community when disturbed, different reproductive abilities of different species, different sprouting abilities of different variants of the same species, the kind of disturbance and its duration and intensity, soil differences, and many others.

The left-hand part of the figure illustrates succession to a new and different potential as a result of various disturbances and pressures on the site that break the chain and preclude succession according to what theory would suggest. Some disturbances can be severe enough to alter the potential of a site for the foreseeable future.

If you stop and think about it, there are many examples of altered potentials. They include:

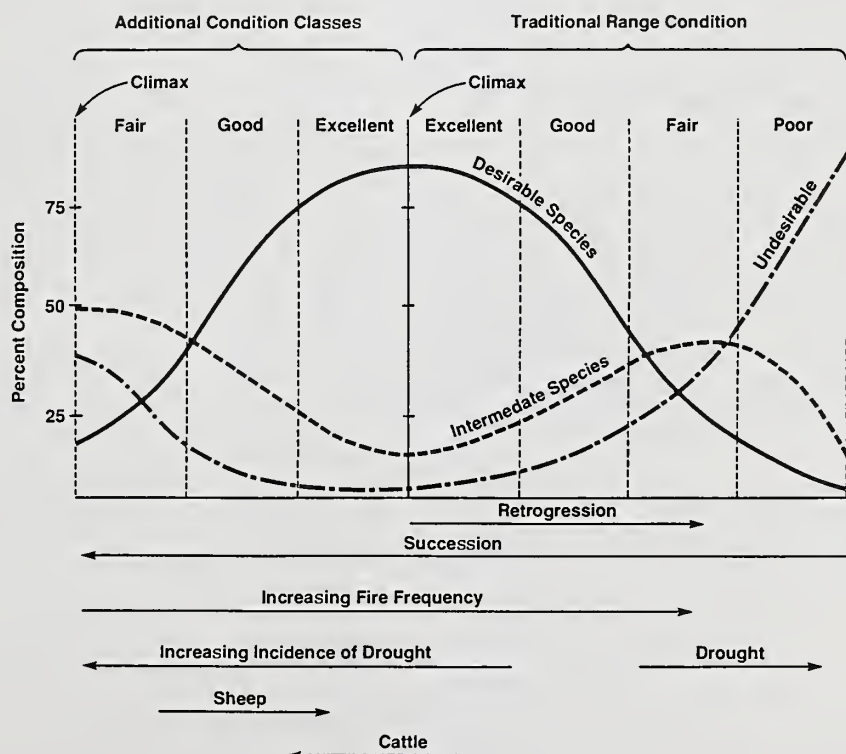


Figure 1--Modification of traditional U.S. concept of range condition to account for climax species composition being less desirable for livestock grazing than earlier successional stages.

the change from a bunchgrass-savannah to annual grasslands in California; self-perpetuating cheatgrass occupying sagebrush-bunchgrass sites in southern Idaho; the subalpine fir sites in and around Yellowstone National Park in a permanent lodgepole pine cover; chaparral occupying pine sites in southern California; and the elimination of the American chestnut from eastern hardwood sites. There are many other examples throughout the United States. Such permanent alterations of potential are even more common elsewhere in the world. If you have a chance, I strongly recommend reading a paper by R. Merton Love entitled "The Range-Natural Plant Communities or Modified Ecosystems?" printed in the Journal of the British Grassland Society, Volume 16, No. 2 in 1961.

After considerable thought about Dr. Love's paper and Dr. Norton's discussion and graph, I redrafted in figure 2 what I think better illustrates the complexity of alternative successional pathways, alteration of the potential as a result of disturbance and the arrest of succession at some stage other than the potential natural community for the site.

Long-Term Arrest

In this rather busy illustration, successional pathways are illustrated as the pages of a book radiating out from the book's backing, which represents the identified potential natural community of a site. In each case, depending on the kind of disturbance and its duration and intensity, retrogression and/or succession differs. The rate of succession may differ depending on any number of factors. Succession may be halted or recycled within a narrow range indefinitely at some point on the successional scale other than at the potential natural community of the site.

On the other hand, succession may follow normal Clementsian succession as it does in Great Plains grasslands. The mechanism and factors that contribute to or cause the alteration of the potential or arrest succession are almost totally unknown or at least poorly known. They are of vital importance, however, to the John Q. Users. The risk or the probability of their occurrence is also unknown and rarely factored into the management prescription when it is applied.

To add to the problem is long-time climatic change, and relatively short-duration change, that have occurred in the recent past. In the 10th century or thereabouts, there is evidence the Vikings landed in Greenland, Newfoundland, and perhaps as far south as Cape Cod. The evidence suggests that the climate was much milder then. By about 1300 AD a significant cooling occurred in the Northern Hemisphere which probably culminated in the Little Ice Age in the late 1700's. Since then we have had warming, then cooling, and now with the rise in carbon dioxide, we anticipate significant warming again.

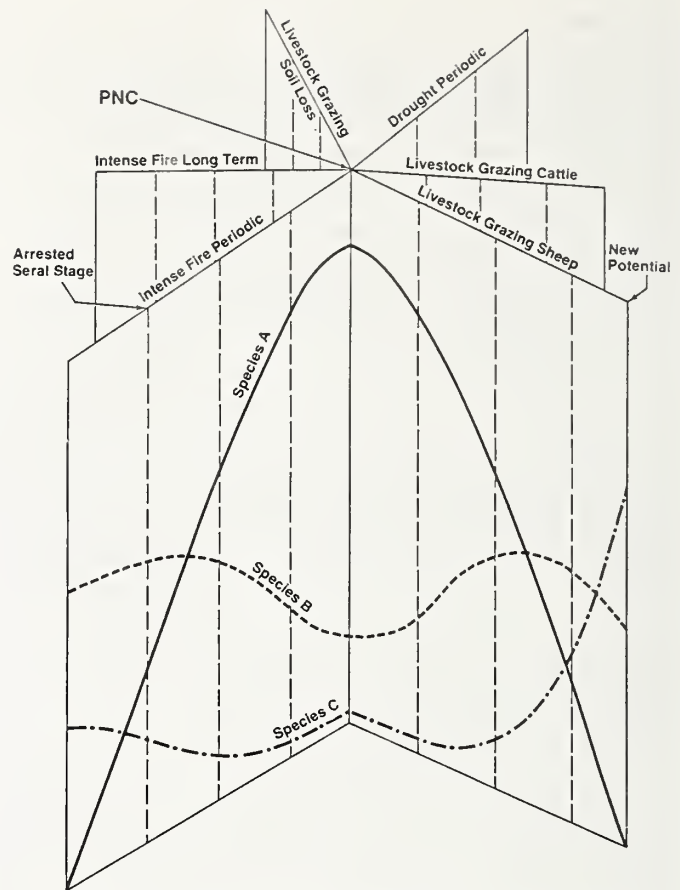


Figure 2--Alternative successional pathways.

Of course, not all communities are affected by such changes. But any community with a narrow margin of sensitivity or tolerance would be. I am not totally convinced, in light of past and potential climatic changes, of the utility of a habitat type classification that identifies a potential that takes 150 years to achieve for other than providing a framework end point and a historical perspective.

The John Q. Users are interested in change as a result of their management next year, in 5 years, in 10 years, and 50 years from now; and how their decisions contribute to the desired future condition of the Forest. They are also interested in the probable condition at the end of the rotation. Most rotation ages have been lowered to 80 or 90 years, and in some places such as the Southeast, to as little as 40 years. The few remaining stands that have weathered 200 to 1,000 years of climatic change and environmental hazards are extremely valuable from a reference stand point, but cannot be practically incorporated into the day-to-day management decisions.

I am going to sprinkle a few grains of salt on this graph to illustrate the problem of exotic and opportunistic species, which may be present at any stage of succession. The chance presence

of such species in early succession may alter the path of succession or alter the final combination of species of the potential natural community of any altered potential or arrested seral stage. This problem is a very real one throughout the United States. I can illustrate this problem by asking you how many sites you know of in the State of Idaho that contain no cheatgrass. The list of naturalized exotic species of all kinds is almost unlimited, but the problem is very real and serious for John Q. User.

Multiple Potentials

To illustrate the problem of multiple potentials within a plant association or habitat type, I further modified figure 2 and came up with figure 3. Many association and habitat type descriptions define a vegetation potential so broad that it overlaps many differences in soils, geology, topography, slope, and aspect. When the site is disturbed, it starts from somewhere within the oval, depending on the particular combination of environmental factors and may or may not follow the successional pathway for a particular disturbance as illustrated.

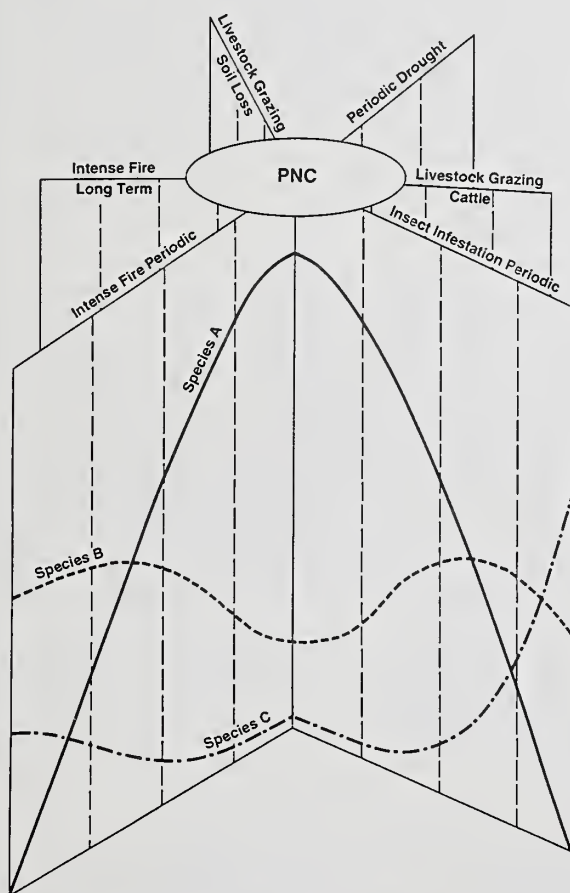


Figure 3--Alternative successional pathways.

More often than not, a new page of the model must be added because the particular environmental combination of the site causes important differences in the successional pathway. A totally new arrested seral stage may result, or a totally new potential, if the disturbance is severe enough. If the succession progresses back to the original potential natural community, that potential may have to be redefined as a new habitat type because of the altered successional pathway that resulted following disturbance and the realization that site potential makes a difference in the management options available.

Some of the refinements of previous classifications, which are and have been taking place recently, are undoubtedly the result of the realization of these kinds of differences.

SUMMARY

In summary, a lot of good work has been done by the Jim Dan D. Classifiers. Some of it is not in use by the John Q. Users for reasons I have explained.

Some classifications are not refined enough by site conditions other than vegetation to adequately identify a usable potential. In most cases ecotones, alternative successional pathways, and early successional development have not been identified adequately enough to satisfy the needs of the John Q. Users. The risk of making a wrong decision is unknown. And finally, some of the traditional concepts of succession need to be reevaluated to adequately identify factors and mechanisms that contribute to the arrest of seral stages for long indeterminable periods, or to the development of new potentials.

The bottom line is that vegetation classifications are not yet user friendly, nor will they be, until the Jim Dan D. Classifiers "get down and dirty" and immerse themselves in John Q. User's problems. They must satisfy needs for short-term early successional predictions that can be used to make rational management decisions and minimize risks of making wrong decisions. In many areas of the West, the easy part of association and habitat type classification is over. What remains is to make the classifications user friendly to all resource users and accommodate the problems I have identified. I don't have an easy answer for getting the job done. I do know it will require a refocusing of effort and a commitment by decision makers. The speed with which it will happen will depend on the severity and frequency of problems we have in implementing Forest Plans and scrutiny we receive from the public.

VEGETATION CLASSIFICATION -- PROBLEMS, PRINCIPLES, AND PROPOSALS

Kristen R. Eshelman, Robert E. Wagner, and Glen M. Secrist

ABSTRACT: There are a number of vegetation classification systems. All seem to be based on different concepts or perspectives. Most provide resource managers with useful, yet often incomparable information. Current philosophies on classification, succession, and condition reporting are discussed from a Bureau of Land Management perspective. A classification method is proposed which would result in improved resource management and condition reporting.

INTRODUCTION

Have people encountered delays or difficulties in arriving at this symposium? Have the American people experienced delays, cancelled flights, lost luggage, near misses, poor meals, and/or exorbitant fares in the last year? Have we benefitted from fare reductions, increased flights, or the merging of inefficient airlines? The answers to these questions are obviously yes.

Within the last 100 years ecologists have presented a number of classification systems to their peers. They have been based on historical, present, and potential vegetation (Bailey 1978; Paysen and others 1980; Allen 1987; Kenner and Allred 1962). Agencies, through resource managers, have adopted their own preferences and suffered the difficulty of not being able to share or compare information without using two different techniques or concepts on the same site(s). Countless dollars have been spent and hours wasted duplicating efforts in an attempt to gain a common understanding of vegetation classification. Inventories have been boxed and stored because a new classification system outdated the old system and its associated procedures.

POTENTIAL VEGETATION VERSUS PRESENT VEGETATION

Vegetation classification systems have been based primarily on potential vegetation or present vegetation. Each has its own degree of usefulness to the resource manager.

Paper presented at the Symposium, "Land Classifications Based on Vegetation: Applications for Resource Management," Moscow, ID, November 17-19, 1987.

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Potential Vegetation

Most potential vegetation classification schemes using perceived potential vegetation as a basis imply that there is only one potential vegetation community that may occur on any given physiognomic unit. Having a description of the perceived potential vegetation as a reference point is useful for making interpretations of present vegetation communities and provides a reference vegetation community for comparison purposes. However, it does not provide a resource manager with sufficient information on other vegetation communities capable of occupying the site, nor does it provide information on the range of natural resource products that might be produced on the site. There is also considerable difficulty and controversy involved in deciding what the climax vegetation was or what the potential vegetation community should be, particularly on those sites long influenced by human activities. Many times potential vegetation classification systems ignore the presence (or potential) of the exotic or introduced organisms that may or will influence the character of a site for centuries to come.

Present Vegetation

Classification schemes based on present vegetation are most often used in resource management because management strategies must be designed with the current situation as a starting point. Present vegetation classification systems often provide the resource manager with information about several optional vegetation communities available as a management objective, and, by having several tangible alternatives, the efficacy and efficiency of management is improved.

However, present vegetation classification systems, utilized without consideration of the potential vegetation, often result in misdirected and futile management. Management, aimed at producing a vegetation community not possible or within the site's inherent capability, has been attempted time and time again. Numerous land treatment projects have been undertaken, only to flourish for a short time, and then fail. Resource managers have received the brunt of the criticism for these so-called failures, when in reality they did not have sufficient information available to determine the true potential(s) of the site.

THE CURRENT SITUATION

Ecological Sites

The Bureau of Land Management (BLM) currently uses the Range Site Concept (Dyksterhuis 1949; Renner and Allred 1962) as adapted from the Soil Conservation Service's (SCS) National Range Handbook (USDA 1976; USDI 1984). The range site concept, as used by the SCS, is based primarily on the perceived historical climax vegetation of a site and is often implied in site descriptions to be the potential climax vegetation or potential natural vegetation for the same site. Site descriptions generally allow a restricted range of variation of associated species and little to no allowance is made for the presence of introduced or non-native species. In the last several years there has been increasing acceptance of incorporating introduced and non-native species into site descriptions. Therefore the Range Site Concept is in essence a classification system based on historical vegetation with occasional allowances made for potential vegetation.

The Ecological Site Concept as used by the BLM is similar to the range site concept but follows the ecological site terminology and concepts as discussed in the Society For Range Management's (SRM) Range Inventory Standardization Committee (RISC) Report (SRM 1983). BLM cooperates with the SCS in the inventory and mapping of the soil resource, as well as developing or modifying range site descriptions.

Successional Concepts -- Range Condition

Range Condition is currently used by the SCS to imply a successional state, whereas the BLM actually states the perceived successional status of a particular site. Both agencies use coefficients of community similarity to determine the range condition of a site. Table 1 illustrates the ranges of similarity and the terms used by SCS and BLM for reporting range condition. Of particular interest is the assumption by each agency that their terms accurately express range condition. The SCS terms assert that the more dissimilar a site is from the perceived Climax Community (excellent condition) the poorer the condition of the site. There is no consideration for the uses or potential uses of the site other than for excellent condition. Even though proponents of the range site concept have stated that the Climax Community is not invariably the primary management objective (Dyksterhuis 1949;

Table 1--Comparison of terms used for reporting range condition.

Percent Similarity	SCS Terms	BLM Terms
76%- 100%	Excellent	PNC
51 - 75	Good	Late Seral
26 - 50	Fair	Mid Seral
0 - 25	Poor	Early Seral

Shiflet 1973), many range management professionals and certainly the American public feel that anything less than Excellent or Good is unacceptable.

The BLM uses terms indicative of seral stage as described in the RISC report (SRM 1983). The presumption here is that a community dissimilar to the Potential Natural Community (PNC) is in an "earlier" seral stage. However, dissimilarity only indicates that the communities are dissimilar, not necessarily in an earlier seral stage. In spite of the use of the ecological terms for seral stage, many range management professionals and the American public again feel that anything less than PNC or late seral is unacceptable.

Since both agencies use the same technique to arrive at range condition ratings, it is assumed by many people that the terms are equivalent. "Early seral" is therefore assumed to be equivalent to "poor," "Mid seral" equal to "fair," and so on. They are not always equal.

The range condition problem for all agencies is similar. In the age of multiple-use management, should we report range condition as "poor" if our primary objective is to provide a reatively early seral habitat, dominated by forbs, for spring pronghorn range? Is reporting seral stage without reference to resource values really providing meaningful information at the national level? Is not seral stage more meaningful at a local level?

What is the condition of a mosaic of late seral sagebrush intermingled with early to mid seral forbs and grasses often considered to be prime sage grouse habitat? Do the terms currently used to report range condition accurately portray the management condition of the western rangelands?

Successional Concepts -- Philosophical

The range management profession developed its grass roots by adopting many of the concepts used by the livestock industry. The perception of what was good condition range obviously correlated to whether or not a cow, horse, sheep, or goat could find a full belly, produce healthy offspring, or find a place to hide from the extreme climate of the West. Range condition was synonymous with Forage Condition. To this day the life forms associated with "good range condition" are perennial grasses, tasty forbs, palatable shrubs, and desirable California annual grasses. It seems that the perceived climax communities on rangelands are usually described as having a dominance of these life forms. We have seemingly placed forage dominated communities at the acme of succession, relegating woody communities and thus woody species to the bottom of the successional pyramid or cone. Foresters on the other hand view the successional cone as always having trees at the pinnacle.

Natural succession is constantly moving many rangelands toward domination by woody vegetation. Sagebrush, pinyon, juniper, etc. are the potential

cover types for millions of acres in the West. Many potential natural communities will be, as were the historical climax communities, dominated by woody vegetation. Why is it that following treatment to reduce sagebrush, we find sagebrush very quickly reestablishing and moving toward site dominance even in the absence of grazing?

What is the reason for calling woody communities lower seral? Are organisms that live 100-300 years truly more indicative of earlier seral stages than are herbaceous plants whose life span is 2-10 years? Shouldn't PNC or Climax be described as the community that develops through succession in the absence of disturbance? Catastrophic disturbance by fire, for example, has and will continue to create and maintain lower seral communities dominated by grasses and forbs.

There has been considerable interest in a disturbance theory of secondary succession. Little work has been done on rangelands, but it is our opinion that recognizing disturbance as a succession-inducing mechanism aids in explaining why wildland ecosystems function as they do. For discussion purposes, disturbance includes fire, chaining, grazing, animal-induced perturbations (badgers, ants, etc.), and seeding. Disturbance also includes weather and climatological events such as hail, intense rain, flooding, severe drought, extreme wind, and extreme temperatures. Recognizing that disturbance is selective, often influencing only a few species, aids in explaining why some species suddenly increase or decrease in an ecosystem. Considering a disturbed ecosystem or site as a lower successional community relative to an undisturbed ecosystem or site would be a major step toward understanding ecosystem dynamics.

Although disturbance implies negative impact, disorder, or chaos, disturbance can be a positive factor for some species and negative for others. Above-normal precipitation as a disturbance may promote the increase of species A, the increased dominance of species A in turn disturbs the habitat of species B, thus causing a decrease in species B.

A disturbance theory can also account for why early successional species often occur with late seral species on the same site. The late seral species have not been disturbed, but disturbances to the soil surface have provided annual weedy species with a receptive habitat. When estimating ecological status how many times do resource managers find late seral sagebrush coexisting with early seral cheatgrass and their coefficient of community similarity calculations end up averaging late seral species and early seral species into a mid seral stage community?

WHAT THE FUTURE MAY BRING

Ecological Site Concept

The ecological (range) site concept is and will remain a useful tool for assessing the productive capability of ecosystems. Soil mapping and soil

survey are and will continue to offer insights into the most efficient uses, potentials, and limitations of the public lands. The techniques to acquire the data used for describing ecological sites will evolve, moving from a productivity basis to a basis that includes other attributes such as cover and density.

It is anticipated that our perceptions of what constitutes the climax community or potential vegetation community will move toward recognizing that many exotic species are permanently established and will remain on our "native" rangelands. We will recognize that nature is in the process of adding species to the earth's surface as well as removing the species we call Threatened and Endangered.

The perception of historical climax for a site being one and only one pristine "pre-European man" vegetation community should change to a perception recognizing that the first European (or Indian) probably saw a number of pristine seral communities in various stages of succession (Burkhardt 1987). It is difficult to imagine that succession did not occur until Europeans arrived.

Seral Communities

The seral community type concept as described by Leonard and others (1987) offers the potential for arriving at a classification system describing both potential vegetation and present vegetation. The seral community type concept allows descriptions of the perceived historical climax, and the perceived potential natural community, as well as the located, sampled, and documented plant communities known to occupy a given soil/landscape unit.

Using any and all sources, the concept basically aggregates data about vegetation communities known to occur on an ecological site. Data sets are segregated based on a common attribute such as production or canopy cover. Samples are then sorted into unique seral communities based on the three or more most dominant species. Table 2 illustrates actual data from one ecological site in California and the resulting community types as sorted to a species composition (air dry weight) of greater than or equal to 5 percent (USDI, BLM 1987.)

Working site-by-site and seral community-by-seral community, the data are analyzed by resource specialists familiar with the area. Data exceeding normal expected values, sampled in ecotones, or sampled by combining two ecological sites, are removed from the database. The similarity indices of each sample are assessed as to their pertinence in describing a particular seral stage. If necessary the seral stage name is changed to one more accurately describing the seral community's seral position, assuming that the review team can agree on successional concepts.

Table 2---Seral community types-Stony Slope South Ecological Site

<u>Potential natural community</u>		<u>Late seral</u>		<u>Mid seral</u>		<u>Early seral</u>	
EPVI	50 %	AGSP	40 %	AGSP	32 %	BRTE	54 %
AGSP	28 %	ARTRV	24 %	CHNA2	19 %	ERIOG	22 %
AMSIN	6 %	LUPIN	10 %	TECA2	17 %	SIHY	12 %
ARTRV	6 %	STTH2	10 %	ASTRA	15 %	ARTRV	10 %
AGSP	29 %	AGSP	64 %	HODI	50 %	BRTE	48 %
PHLOX	17 %	ERIOG	12 %	RIBES	25 %	ERIOG	39 %
AAFF	13 %	PHLOX	12 %	ELCI2	11 %	SIHY	7 %
PHAC	13 %			ARTRV	6 %		
ARTRV	9 %						
		AGSP	35 %	PUTR2	26 %	TAAS	46 %
		EPVI	33 %	ARTRV	24 %	BRTE	19 %
		ARTRV	19 %	AGSP	22 %	EPVI	15 %
		BRTE	5 %	CHNA2	13 %	AMSIN	7 %
				AGSP	53 %		
				BRTE	26 %		

The final step in the analysis process is to address the causal agents that may have been involved in creating each seral community type. For example, if monitoring, inventory, or professional observations have detected that a fall prescribed fire causes seral community A to consistently become a seral community B, fall prescribed fire is listed as a causal agent between seral community A and seral community B. The important point with this last step is that documentation of causal agents should eventually lead to improved management. Many cause and effect relationships are discussed in the literature, but few resource managers or livestock producers have the time to search the literature for the cause and effect relationships pertinent to the ecological sites in their area. In addition, the documentation of cause and effect relationships in local ecological site descriptions will allow resource managers and livestock producers a means to document their knowledge and experiences without having to endure the often lengthy and laborious process of publishing their findings.

Rangeland Condition Reporting

As previously discussed, range condition has been historically biased toward domestic livestock; many people perceive potential (climax) vegetation as containing a major component of livestock forage species. Only within the last decade have we begun to recognize that nonforage species are an important component of an ecosystem. The passage of the Federal Land Policy and Management Act of 1976 sent a formal declaration to the BLM that the Public Lands should be managed using the principles of multiple use and sustained yield.

The Public Rangelands Improvement Act of 1978 (PRIA) defined range condition (for Federal land management agencies) in Section 3(d) as:

(d) The term "range condition" means the quality of the land reflected in its ability in specific vegetative areas to support various levels of productivity in accordance with range management objectives and the land use planning process, and relates to soil quality, forage values (whether seasonal or year round), wildlife habitat, watershed and plant communities, the present state of vegetation of a range site in relation to the potential plant community for that site, and the relative degree to which the kinds, proportions, and amounts of vegetation in a plant community resemble that of the desired community for that site. (Emphasis added)

Congress clearly stated that it desired a multiple-use-based report that considered Land-Use Plan and Range Management Objectives. The BLM is currently investigating an alternative method for reporting how well the Public Lands are meeting the Land Use Plan's resource objectives. The BLM is considering reporting "Ecological Status" and "Management Status" in lieu of the old term Range Condition. Ecological Status would be reported using the criteria discussed previously, whereas Management Status would be a new term but not really a new concept to the range community.

Using a key term taken from PRIA, Management Status would be based on how well a tract of land was producing vegetation in comparison to the "Desired Plant Community" or Desired Plant Communities for the same tract. Using an interdisciplinary team and public input, the desired plant community(s) for a tract of land would be selected from the seral community types documented and shown to be capable of occurring on

the tract. In some cases the desired plant community might only be a description of that proportion (or ranges of proportions) of trees, shrubs, forbs, or grasses needed to meet the needs of the resources concerned.

Vegetation Management Status would be determined by using a coefficient of community similarity to compare present vegetation to that in the Desired Plant Community. Terms used to report management status could be very simple such as "Meeting the Vegetation Management Objectives" (greater than 75 percent similarity) and "Not Meeting the Vegetation Management Objectives" (less than 76 percent similarity) or could be more qualitative such as "Excellent," "Good," "Fair," and "Poor" using the same coefficient of community similarity criteria as shown in table 1. Use of the latter terms would allow comparison to historical range condition reports, but could cause confusion since the new system (which uses a combination of ecological status and resource value rating to arrive at a desired plant community) could not be directly compared to the old system (which was based primarily on forage condition).

Trend could be reported by determining whether the present community was moving "Toward the Desired Plant Community(s)," "Away From the Desired Plant Community(s)," or "Not Apparent." Other optional terms could be the terms "Toward the Vegetation Management Objectives," "Away from the Vegetation Management Objectives," or "Not Apparent."

A simple example may aid in understanding the principle. A management unit is predominantly loamy upland, characterized by as much as 50 percent sagebrush canopy with a moderate understory of perennial herbaceous vegetation. The same ecological site outside the management unit produces seral communities dominated by bitterbrush, sagebrush, or significant amounts of perennial grass. The major Land-Use Plan objectives are to provide winter and spring habitat for a resident deer herd, provide year-round forage for livestock, provide habitat for sage grouse, and to prevent accelerated erosion.

Through interdisciplinary review and cooperation, one-third of the unit is meeting the LUP objectives by producing a good mixture of sagebrush and herbaceous vegetation. One-third of the area is targeted for prescribed burning to enhance grass production, whereas the remaining one-third requires special grazing practices to enhance bitterbrush production. Under the old range condition concept the entire management unit would probably have been reported to be in fair condition. But, under the proposed concept one-third would be reported as meeting the LUP objectives and two-thirds would be reported as not meeting the LUP objectives.

Public Lands that are of low potential (creosote bush and shadscale) would be reported as "Meeting the Vegetation Management Objectives" if the LUP indicated that it was technologically not feasible or uneconomical to convert low producing sites into short-term productive ones. Under the BLM's

Selective Management approach most of the acreage occurring within the "Maintain" or "Custodial" categories could be reported as "Meeting the Vegetation Management Objectives."

A CALL FOR ANALYSIS AND CHANGE

Present and Potential Vegetation

A classification system, to be usable to the resource manager, must be able to accommodate historical, present, and potential vegetation concepts. The seral community type concept, as discussed in this paper, offers one possibility as a classification system incorporating both present and potential (as well as historical) vegetation concepts. Use of such a system would allow all agencies, disciplines, and resource users access to the same information, and still allow each to apply their own concepts to the data.

Cover and Production

For obvious reasons, different classification systems depend or are based on different attributes of vegetation. Some use cover, some use productivity. In the computer age why not do both? Even though cover and production cannot be directly correlated, they both provide useful information. Canopy (crown) cover appears to be the most universal attribute since sampling can be performed fairly easily on almost all ecosystems. Cover also relates to a considerable number of multiple-resource-related data needs, including wildlife habitat cover, watershed management, and fire management. Productivity is valuable for establishing forage value and suitability, and for making estimates of site potential, but is difficult to sample uniformly over all ecosystems.

National Standards and Review Committee

The title of this paper could have been "Deregulation of the Classification Industry". To some, deregulation means freedom to do what one desires, the ultimate to those in scientific pursuits. To others deregulation means chaos, an inability to achieve consistency, and difficulty in comparing information. The economics of deregulation are difficult to assess. On one hand deregulation produces cost reductions, on the other we waste time reinventing the abacus. Classification must be standardized. It is amazing that the most scientifically advanced Nation on this planet has no means to make a common comparison among all ecosystems and among all agencies, State and Federal.

A national committee should be established to develop a National Ecological Classification System. This national committee could be patterned after the National Cooperative Soil Survey, a now effective and functional group. A vegetation-oriented group (including, but not limited to, range, forest, and wildlife ecologists) would be more complex considering the differences of opinions on ecology, succession,

terminology, and methods; but should the group prove to be successful, resource management would step into a new era, driven by the availability of new common knowledge and, by cooperation.

Range Condition

Range Condition has been a controversial subject for nearly a century. In the early years of range management, range condition was forage condition; cattlemen had (have) different ideas on range condition than did (do) sheepmen. Today the perspective of range condition has expanded to wildlife habitat, watershed protection, wilderness values, recreation, etc. It is time to change the way we determine and report resource conditions. We have presented an alternative that may provide a wide-spectrum classification system, an improved management tool, and possibly an improved condition reporting system that will substantiate improved multiple-use resource conditions on the Public Lands.

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ON FURTHERING THE USE OF HABITAT CLASSIFICATIONS IN WILDLIFE HABITAT
MANAGEMENT IN THE NORTHWESTERN UNITED STATES

James M. Peek

ABSTRACT: Vegetation classifications are used extensively in wildlife habitat management activities in the northwestern United States, but are likely to be used more as habitat management becomes more intensive. Currently, most attention is given to stand structure and plant succession, without extensive consideration of site potential. Currently, the need to monitor the results of habitat management recommendations is a high priority, but eventually predictions of vegetative and animal response, geared to site potential to produce certain kinds of vegetation, should receive more effort. We have tools to predict plant succession, coordinate vegetative manipulations over large areas, and an understanding of habitat use patterns of elk which could be used to initiate this kind of planning effort.

INTRODUCTION

In order to understand where wildlife habitat managers and researchers might advance in the area of keying wildlife to better habitat descriptions, we might start with a bit of history. First, it might be worth recognizing that even prior to Leopold wildlife conservationists were aware of the need to adequately describe habitats wildlife used. Herbert Stoddard's efforts to enhance bobwhite populations in the southeast involved understanding pathways in plant succession and efforts to manipulate succession with fire. Some of the early impetus to identify what the undisturbed vegetative component consisted of came from wildlife biologists. Wallace Grange was among the earliest to identify and understand how trends toward climax in the Wisconsin forests adversely affected deer and grouse populations.

However, from the practical management side of wildlife conservation in the western states and elsewhere, two major efforts have occurred over the past 40 years that are based on understanding plant succession and climax. The

effort still in practice is the seral shrub burning program, instituted in the 1960's, to retain and enhance big game winter range. The landmark monograph on succession in the cedar-hemlock zone of northern Idaho by Mueggler (1965) described the vegetation, while the work of Leege (1969) and his colleagues describes results of the burning programs. This work eventually led to expansions of the program to summer-fall burning on critical winter-spring range complexes, as distinguished from just the so-called critical winter range. Prescriptions and descriptions of fire's effect on various forested communities have emanated from this early work, in ponderosa pine (Merrill and others 1982), bitterbrush (Bunting and others 1985), and more mesic habitat types (Zimmerman and Neuenschwander 1984; Lyon 1971, 1976). The prescriptions that allow wildfires to burn in wilderness were supported by wildlife biologists, who saw benefits to wildlife, as well as the restoration of a natural dynamic process.

The other major area dealt with condition-trend evaluations of winter forage on rangelands. Big game winter range management has often been based on the assumption that productive shrub and grasslands at near climax condition were the goal, and experience with the wildlife management areas that provided winter range has shown this goal to be achievable. The descriptions of habitat types such as those of Daubenmire (1970), Mueggler and Stewart (1980), and Hironaka and others (1983) all provide information on what the vegetative potential is for different sites. This activity has been severely curtailed because of methodological problems, no apparent correlation between population trend and vegetative condition, and changes in priorities.

While these activities have been institutionalized to varying degrees by the agencies dealing with wildlife habitats, perhaps the area where most interest has been directed recently is in the management of forested habitats used by big game as summer and fall range. There were no real incentives to worry over this issue until logging became more pervasive in the early 1970's. The elk-logging guidelines were developed to help coordinate forestry and wildlife habitat management (Leege 1984). These guides, when initially considered, demonstrated the lack of sufficiently detailed information on habitat use patterns of the various wildlife species.

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This subsequently lead to a wide array of habitat use studies, especially of elk and a few of the endangered or rarer species, that helped to bridge a fundamental communication gap between resource managers.

Early descriptions of use patterns which used highly subjective terms like open versus dense forest were not adequate. Now, with the advent of telemetry and the habitat type classifications, a location of an animal can be pinned to a rather specific site, the floristics, both current and potential of which, can be described. So the habitat type classifications have served as a major vehicle by which wildlifers and foresters have been able to more effectively communicate with each other. I believe this in itself is one of the most significant benefits of these plant community descriptions.

There is still a major problem dealing with terminology, however. Habitat type, as a concept dealing in plant community classification, relates to site potential and is a very specific term. However many wildlifers use habitat type in a more generic context to mean currently existing vegetation. This dichotomy persists and one needs to be certain all involved understand which definition is being used. However, wildlife biologists should recognize the more specific definition of habitat type and refer to the current vegetative complex as the cover type.

Site potential to support a given vegetative complex is important, but the wildlife biologist most often focuses on plant succession and vegetative structure. For instance, redstem ceanothus, the major browse species in north Idaho, exists as a major seral species following fires in a variety of habitat types from those in the Douglas-fir series through the grand fir series into the cedar series. Management to retain redstem should eventually be predicted according to the habitat type involved, but currently an inspection of plant condition is often sufficient to determine management. Plant succession is being manipulated and the focus is on maintenance of a specific seral stage without much concern for site potential.

However, prescribed burning programs on big game habitat are now being expanded to include areas away from the lowest and driest southerly exposed slopes. Vegetative response to burning will differ on various exposures, moisture regimes, and habitat types. As these programs become more prevalent, a knowledge of site potential and plant succession following burning on different areas will be needed.

At the opposite end of the successional sequence, old-growth-dependent species require specific kinds of stand structure, such as large snags for nesting. While even here succession is ultimately involved, retention of old-growth habitat with certain characteristics is the usual management approach. However the

need to predict where old-growth with desired characteristics occurs and will occur in the future will inevitably involve determinations of site potential.

Investigations into plant succession and into management for certain stand structures are important in wildlife habitat management. Efforts to identify seral stages that are preferred habitats must be based on descriptions of vegetative seres and associated structural characteristics, and related to site potential.

Currently, management considering the habitat type exists in certain instances. Critical habitat for mountain caribou on the southern limits of their range is identified as the upper limits of hemlock/pachistima in early winter and the subalpine fir/beargrass and subalpine fir/menziessia habitat types in late winter (Scott and Servheen 1984). Moose prefer to winter in the Pacific yew phase of the grand fir/ginger habitat type in central Idaho (Pierce and Peek 1986). While the native big game species exhibit broad habitat use patterns that include many habitat types, even white-tailed deer habitat use patterns can be predicted at the habitat type level (Owens 1981). Dense seral stages of grand fir/pachistima and cedar/pachistima habitat types were preferred deer habitat on the Palouse Range. White-tailed deer preferred to winter in unburned Douglas-fir/ninebark in the upper Selway River, Idaho (Keay and Peek 1980). Jageman (1984) was able to relate habitat management for white-tailed deer to habitat type, stand type, site index, and successional patterns within habitat types.

The habitat type was one significant predictor of elk habitat preferences on the Gospel-Hump area in central Idaho by Scott and others (unpublished manuscript). Ponderosa pine/bluebunch wheatgrass was highly preferred elk winter habitat on the Salmon River drainage in this area. However, Irwin and Peek (1983) reported elk using a variety of successional stages in several habitat types at different times of the year in north Idaho, which illustrates variability of use patterns and potential predictors of habitat use for this species between different areas. Many of the nongame birds have habitat requirements most appropriately keyed to stand structure, with assessment of site potential being of less utility.

Habitat use patterns of mule deer on rangelands can also be readily related to site potential. In north-central Washington, Carson and Peek (1986) reported that riparian communities were preferred habitats, with the most xeric sagebrush stands, especially those in poor condition being least preferred. Three-tip sagebrush communities were favored winter deer habitats in east-central Idaho (Moir 1976; Wittinger 1978; Kvale 1981; Yeo 1981). Recently burned Douglas-fir/ninebark and ponderosa pine/bluebunch wheatgrass habitat

types were preferred winter mule deer habitat in the upper Selway River drainage, Idaho (Keay and Peek 1980).

The bluebunch wheatgrass/Sandberg bluegrass habitat type is common across montane rangelands in Idaho, Oregon, and Washington. Bodurtha (1987) reported that stands in high condition, and mid-seral stages with high vegetative diversity were preferred mule deer habitat. This initial effort to relate wildlife habitat use to a grazing-induced sere in a major habitat type should be extended, as a means to further integrate range management activities with wildlife habitat management.

Site potential turned out to be extremely important in determining management for ponderosa pine stands with bitterbrush understories that occur in the Salmon River canyonlands in central Idaho. Many of these stands are in the Douglas-fir/snowberry habitat type, and will eventually succeed to communities devoid of bitterbrush (Peek and others 1978). One appropriate prescription includes selective cutting and site scarification to foster bitterbrush seedling establishment. Identification of the habitat type in which these important stands occurred was the impetus for considering appropriate alternatives to manage the stands as valuable winter range for big game.

I consider the habitat management guidelines that are available for the various wildlife species to be well-thought-out initial efforts at attempting to integrate forestry, rangeland, and wildlife habitat management. However, they are considered general guides intended for use over relatively large areas that must be tailored for specific conditions. As these recommendations become more widely applied, the need to monitor wildlife and vegetative responses becomes ever more critical. While this monitoring problem is most critical, the need to develop more quantitative approaches to integration of wildlife habitat management and forestry practices is also apparent. Tools are now available to do this. The stand prognosis model developed by Stage (1973) has been extended to include understory and shrub responses by Moeur (1985). Using these predictive models, and mapping systems which determine spacing, size and interspersions of stands through time, we can describe models of vegetative change for specified population entities, such as one elk herd. The available habitat use data for this species could be readily incorporated into such analyses for many areas in this region. Access management plans can readily be integrated into this procedure. Eventually, we will need to transfer more of our efforts toward predictions rather than just on mitigating currently planned activities using the available guides. There is now sufficient knowledge concerning plant succession, stand development, and habitat use patterns to do this at least for

elk. As we get into such efforts, the habitat type once again will serve as the primary basis for communication and cooperation.

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RESEARCH AND INFORMATION NEEDS FOR LAND CLASSIFICATIONS BASED ON VEGETATION

Robert D. Pfister

ABSTRACT: Research and information needs are summarized from two sources: symposium speakers and a poll of symposium participants. Meeting these needs will require coordination and cooperation from research, management, and educational organizations. Numerous opportunities exist to advance the science of applying ecological information to natural resource questions, but these opportunities will not be realized without individual and corporate dedication.

INTRODUCTION

Where do we go from here? What are the next logical steps for application of ecological land classification to natural resource management? This involves documenting research and information needs, but it is not that simple because research needs implies research responsibility and information needs implies what managers need from research and educational organizations.

We all know that managers and management agencies also have a strong hand in developing and disseminating information. The question is not simply, *what is needed?* The real question is, *who will provide it?* We have not reached where we are today by a simplistic approach and we will not progress very fast unless we look at the future with a more cooperative, coordinated, and holistic perspective.

This paper will list research and information needs, but before we do, let us address the framework and perspective necessary to move forward in meeting those needs. Everyone in this room has a vested interest, and many have a professional responsibility, or at least an opportunity, to assist in meeting these needs.

APPLICATION CONCEPTS

Earlier, I discussed a number of points under the heading of Application Concepts (Pfister this symposium). The main points are repeated here, because all are essential in moving forward to continue to meet research and information needs:

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Decision About the Kind of System--This process has been completed by some agencies for some ecosystems. Formal ecology programs have been developed by most USDA Forest Service Regions to complete the classifications, develop management applications, conduct training, and do whatever is necessary to provide for the needs that research and educational organizations have not met (for example, Allen 1985). These programs have a large influence on all natural resource research and management within their geographic area.

However, deliberation is still in progress for rangeland ecosystems and riparian ecosystems in most areas and for all ecosystems within some agencies. Land management and research organizations need to decide what kinds of ecological classification systems are most appropriate (coordination of research and management on this decision is vital).

Planning, Finances, and Personnel--Once basic decisions are made, the plan specifies the tasks, priorities, timetables, finances necessary, and responsibilities. This is the opportune time to document coordination and shared responsibilities of researchers, managers, and educators. Once the plan is approved, qualified personnel must be obtained to carry out the program.

Developing the Taxonomy--Whether termed research or administrative study, quality control (from data collection through analysis, interpretation, and publication) is critical and requires scientists with solid ecological credentials. Methodology is quite well documented, but improved techniques should be continually sought. Shortcut approaches have been suggested, but many are poorly conceived and fail when put to the application test.

Training the Users and Application Specialists--Training is crucial and includes understanding of concepts, indicator species recognition, proper use of keys, mapping techniques, and proper interpretation of available management implications. Research and management specialists who are developing new applications need the training just as much as other users.

Developing Applications for Natural Resource Management--Applications require development of the relationships between the ecological classification (and the ecological knowledge contained therein) and appropriate natural resource concerns. This can be done in several ways:

a. By ecologists, from supplementary data and observations.

b. By research specialists who stratify their data, analyze, and report results in relation to habitat types.

c. By management specialists, summing up their own data, observations, and experience to develop their own local (usually informal) guidelines.

d. By teams of ecologists, resource scientists, and management specialists, pooling their combined knowledge and intuition for a synergistic, documented contribution to knowledge.

e. By symposia such as this one! Concepts for application (or linking of site classifications to resource management) have been evolving for some time and this symposium is the first formal effort to assess how far we have progressed. New ideas and concepts require time and understanding of their value to be accepted and implemented.

Each of the approaches has some problems. Many ecologists do not have a strong background in the natural resource areas where interpretations are needed. Many research specialists do not have enough ecological background to make full use of the classification. Management specialists may solve their current, local problems but there is no mechanism to capture the knowledge for use in other areas. Team efforts offer the most promise for solid, documented applications. However, team efforts require cooperation, coordination, commitment, and support of upperlevel management. If formal team efforts are not possible, it behooves professionals to find a way to work cooperatively with other professionals for specific areas of concern.

Symposia are an effective way to provide a documented update on status of knowledge--this symposium goes a critical next step by addressing the question--"Where do we go from here?"

HISTORICAL PERSPECTIVE

The historical perspective provides understanding of how we got to where we are today--and some lessons for the future. The association concept was established in the late 1800's, discussed in the early 1900's, and first developed as a practical site classification tool in the U.S. with the introduction of the concept of "habitat type" by Daubenmire (1952). During the 1960's, some specialists began applying the classification to natural resource questions, graduate students were developing classifications for new areas, and a few professors were training undergraduates in the concepts and practical aspects of using the classifications.

The 1970's were the heyday of developing classifications for new areas and the beginning of applications. Land use planning began to incorporate ecological concepts. The USDA Forest Service, both Research and the National Forest System, provided financing and personnel to expand classification systems to areas not previously studied. Professors provided guidance to a large number of graduate students developing classifications for new areas.

Many researchers began to use the classifications as a research tool for stratification and inter-

pretation of results in a format that could be applied back to specific ecosystems. Formal training sessions were established to enable a wide range of natural resource professionals to apply available classifications and management implications to natural resource management questions. Some universities developed special courses designed to equip the graduate with the skills to apply ecological classification the first day on the job; and many employers required this educational background as a job prerequisite.

What has happened during the 1980's? What started as a research program has become almost entirely a development and application program. Research funding for ecological classification work has almost disappeared, both internally within research organizations and as grant funding for professors to support graduate student programs. Some justify this state of affairs by saying, "the research has been done." Others, closer to the subject, agree that the classifications (taxonomies) are the means to the end, not the end in itself, and that current management applications are only the tip of the iceberg. We are at a turning point, or may have already passed that point, and the enthusiastic participation in this symposium illustrates both concern and promise.

Fortunately, those land management agencies with sufficient resources (such as the National Forest System) have accepted almost full responsibility for carrying on the classification and application responsibilities. In effect, they are now running true RD&A ecological programs with minimal research involvement and minimal opportunity for university research and education involvement. Coordination and cooperation are far less than optimum for a RD&A concept of such great potential.

ECOLOGICAL AND NATURAL RESOURCE SCIENCE

If we accept that science involves four basic steps--observation, description, classification, and abstraction--then, how far has the science of applying ecological concepts to natural resource management progressed? Classification is "completed" for some areas, although refinements would undoubtedly add precision. Choices, or perhaps a balance of effort, are needed between using resources for continual refinement versus getting on with the job of abstraction.

But, who is going to do the abstraction? If the science is expected to progress past step three, then scientists need to be presented with both the challenge and the opportunity to proceed with the process of abstraction.

One product of abstraction is simplification--which makes the job of classification more efficient for new areas and provides a better basis for effective education and training. Another product of abstraction is understanding of the basic ecological relationships and processes--which leads to better application of the information. A third product of abstraction could be improved linkage of ecological information to natural resource

questions--which is the central thrust of this symposium.

Three major obstacles have been slowing down advancement of the science of applying ecological information to natural resource management. The frustrating aspect of these obstacles is that they are internal--as Pogo (comic strip) said, "We have met the enemy, and he is us!" Lee Iacocca (of Chrysler fame) labels this kind of problem as "identifying the naysayers within an organization and getting rid of them!" (Easier said than done in most organizations!) The three problems I refer to are:

Inadequate Research Support--Forest Service Research deserves major credit for developing, financing, and publishing much of the classification and application work during the past 20 years. The Forest Service definition of research is: a) development of new knowledge and b) new applications of existing knowledge through improved techniques and methods. Development of classifications for new areas fits the first definition in the minds of most ecologists who realize that each new area has unique species-site interactions to be discovered--development of new knowledge. The naysayers argue that this is really development work, since the basic concepts and methodology are established. Nevertheless, Forest Service Research does not have sufficient resources to complete classifications for all areas--other sources of research funding must be found.

University Negativism--It is disconcerting to hear of professors in Forestry Schools who will not allow prospective graduate students to develop a habitat type classification for a thesis (because it is not a new concept!) or where ecology professors are discouraged from working on habitat type classification and application. On the other hand, few of us would be here today without those professors and universities who encouraged continued research and development of the habitat type concept for new applications to natural resource management. Since this problem varies greatly among universities and professors, we have the freedom of choice to select those universities that have the capability and desire to help meet the research and information needs we document here.

Management Program Isolation--With inadequate research funding and incomplete university support, some management agencies have found it necessary to develop their own special programs to get the job done. The Ecology Program of the USDA Forest Service Pacific Northwest Region is the most familiar example. Most Forest Service Regions in the western United States have, or are developing, similar formal programs. However, if the science is going to be done by a management agency alone, then there is an obvious danger of just mechanically and routinely getting the task done. If scientists are hired to expand the system, what happens to their new ideas and concepts? Do they have the opportunity to document and present these for the advancement of science? Is the management agency really doing research, or can it all be

called administrative study? Some administrators get nervous when these questions are asked. Fortunately, the Chief of the Forest Service sent a letter to Stations and Regions in the early 1970's. This letter basically stated that we shouldn't get hung up on technicalities--there was necessary work to be done and that Regions and Stations should cooperatively get on with it. Farsighted administrators have found ways to get the job done and contribute to advancement of the science.

Much of the progress to date has been achieved through informal research, development, and application programs. The RD&A concept works very effectively. It can resolve most of the obstacles mentioned above. It also can include education needs that have been discussed. If informal RD&A concepts are not being utilized, then formal programs may be necessary to get the jobs done.

RESEARCH AND INFORMATION NEEDS--SYMPOSIUM SPEAKERS

Many of the speakers in this symposium have discussed needs (directly or indirectly) in their presentations. Some of their major points are summarized in this section:

Wellner listed seven points in his paper under the major jobs ahead:

1. Completing gaps in classifications.
2. Correlating existing classifications.
3. Developing classifications for seral communities with pathways and management implications.
4. Refining classifications.
5. Mapping of habitat types.
6. Developing better productivity estimates of each habitat type.
7. Fitting classifications by habitat types into an overall land classification framework.

Bourgeron listed four major points:

1. Correlation of local classifications at a regional or continental scale.
2. Models of diversity patterns at different levels of ecological organization.
3. System for managing ecological information.
4. Guidelines on conserving and managing units of classification.

Johnson emphasized the obvious need for more training as revealed by a survey.

Roberts and Morgan, Keane, Steele, and other speakers have all emphasized the major lack of information available on successional communities, even when the habitat type classifications are completed. Techniques for studying succession have been explored and proposed, but working models and classifications for seral community types will require a major effort for each geographic area of concern.

Hann discussed several problems in application that can be solved by:

1. Increased training.
2. Increased emphasis on correlation with other environmental factors.

3. Development of an ecological data base system.
4. Predictions based on seral classification and modeling.
5. Area evaluation in addition to stand evaluation.

Neiman and Hironaka pointed out some of the benefits that could be obtained through better knowledge of the correlations between potential vegetation, soil, and site characteristics within a specific region.

Schlatterer discussed three major needs:

1. Refinement by other environmental factors to adequately identify a usable potential.
2. Identification of mechanisms and factors that contribute to the arrest of seral development for long periods, or to the development of new potentials.
3. Modifications to satisfy the needs of the user for short-term predictions in early succession that a manager can use to make rational decisions.

Tisdale stated several needs relative to shrub-steppe areas:

1. Extension of classification to new areas.
2. Refinement of existing schemes in light of increased knowledge.
3. The biggest challenge--develop a better understanding and a workable classification of ecosystems supporting seral vegetation.

Volland described the need for and a new process for development of forage rating guides that is integrated with vegetation and site classification concepts.

Klebenow recognized the formidable need of outlining plant composition for all the seral stages of each ecological site, and concluded that research was needed to get a full understanding of the relationship between the successional stages of an ecological site and the reaction of wildlife.

Stage emphasized the need for "conservative involvement" of revised classifications to make application developments more efficient.

Lyon reminded us that we must remember to be careful in all our enthusiasm. Research has things like statistics, experimental design, and peer review that are necessary to help us maintain objectivity.

Leonard and Miles recognized the lack of a unifying force for vegetation classification and interpretation in the broader sense--and that this force must come from, and involve, the major users of vegetation classification systems.

Other speakers have provided emphasis to the above points. The list of needs is overwhelming and priorities must be established. Who sets the priorities?

RESEARCH AND INFORMATION NEEDS--SYMPOSIUM PARTICIPANTS

During the symposium, I invited participants to write down the two most important research and information needs from their perspective. A total of 221 suggestions (which are summarized in Table 1) were received from 108 participants. Participants were asked to identify themselves as "researcher" or "user." Some found it difficult to identify cleanly with those two categories.

To summarize results, I included all ecologists actively developing classifications in the "research" category and all other kinds of staff specialists in the "user" category. There were still 15 that did not fit or did not identify themselves by category, which are identified as "unspecified."

The needs were listed by categories relative to previous discussions. Research and development needs are pooled, so that we do not point fingers at responsible organizations (the responsibility must be shared). The first group relates to vegetation (and site) classification--the foundation. The second group relates to management applications--the relationships that can be developed once a standard taxonomy is available. The third group is simply labeled as application, which lists some good suggestions relative to some possible direct uses of the classifications in land management. The fourth category, education, is a crucial part of furthering regular application by managers (and other research disciplines). The fifth category, administration, includes those comments from participants who recognized that the best ideas may never come to fruition without commitment from the top.

All needs are listed. Similar responses were paraphrased as recurring themes. Those needs with the highest scores provide a strong indication of where this audience thinks we should be going. Unique ideas were also listed. (Unique ideas may be "far out" or "new perspectives" or "locally important"--readers may make their own judgments.)

DISCUSSION

The three major items that must be addressed are succession, applications for resource management, and training. There are alternatives to tackle each of these needs.

Succession--If you look at the job of doing succession work with a complete sampling approach, it appears to be 10 times the task of the original habitat type classification work. Who is going to finance that size of a job? One participant suggested that the size of the problem could be partially solved by having management agencies help develop the data base. Is succession an area for research to look at methods of tackling this problem more efficiently? We have had some other good suggestions during the symposium. The next major scientific breakthrough may well be an efficient way to handle the numerous questions about successional relationships.

Table 1--Summary of research and information needs from 108 participants (R=Researchers, U=Users, N=Not specified or other)

Research or information need	(R/U/UN)
A. RESEARCH AND DEVELOPMENT--VEGETATION CLASSIFICATION	
1. Develop successional pathway models and classification of seral communities (including treatments).....	(31/13/1)
2. Need to coordinate, unify, or standardize concepts and approaches of classification to meet needs of users.....	(12/10/3)
3. Develop habitat type taxonomies for all areas not adequately covered.....	(10/3/0)
4. Determine relationship between vegetation classification topography and soils (to improve site specificity).....	(5/6/1)
5. Develop multifactor (ecosystem) approach to classification that integrates vegetation, soils, landform, wildlife, and all resource needs.....	(4/2/3)
6. Develop regional correlations of classifications (including assoc.and range sites)...	(4/3/0)
7. Develop analytical procedures for portrayal of successional stages and habitat types within a large area of analysis (landscape ecology).....	(0/1/1)
8. Develop more concise objectives for classifications in order to test the validity (utility) of these classifications.....	(1/0/0)
9. Correlate ecological and genetic parameters.....	(1/0/0)
10. Develop comprehensive models of vegetation behavior within types.....	(1/0/0)
11. Resolve the question of whether an individual species is a better definition of a "responding unit" than a "community class" and proceed accordingly.....	(0/1/0)
12. Take a hard look at the assumption that Daubenmire's classification concepts/methods apply wholesale to forests or nonforest vegetation elsewhere.....	(0/1/0)
Subtotal-Part A.....	(70/39/9)
B. RESEARCH AND DEVELOPMENT--MANAGEMENT APPLICATIONS	
1. Develop (synthesize, summarize, test, and refine) management interpretations and natural resource applications of habitat types (and successional stages).....	(12/8/5)
2. Develop methodology to improve relationships of habitat types to productivity.....	(4/3/0)
3. Determine relations between habitat types/successional stages and insects/diseases ..	(2/0/0)
4. Provide an understanding of long-term effects of forest use.....	(1/0/0)
5. Ecotone identification and mapping techniques.....	(0/0/1)
6. Techniques for application of vegetation classification in management of natural areas and in use of undisturbed areas as a comparison to disturbed areas.....	(0/0/1)
Subtotal - Part B...	(19/11/7)
C. APPLICATION	
1. Mapping of vegetation to include both current and climax potential vegetation (and site factors).....	(2/0/0)
2. Compatible inventory methods to integrate vegetation and soils as a basic resource stratification for planning.....	(3/1/0)
3. Define mangement needs and the data required to meet them and integrate into uniform workable inventory procedures.....	(1/1/0)
4. Test the risk and consequences of misclassifications.....	(1/0/0)
5. Development of a "holistic" approach to land management.....	(0/1/0)
Subtotal - Part C.....	(7/3/0)
D. EDUCATION	
1. Education and training for all users of classifications (concepts, application, and acceptable interpretations).....	(23/11/6)
Subtotal - Part D...	(23/11/6)
E. ADMINISTRATION--ALL ORGANIZATIONS AND AGENCIES	
1. Need agreement on desired vegetation classification system--and then, a commitment (funding) to develop it.....	(0/2/4)
2. Increased cooperation/coordination among agencies (and support service) in classifying vegetation.....	(1/3/2)
3. Provide means to enhance communication among those involved in vegetation classification (workshops, etc.).....	(1/1/0)
4. Get research organizations back into vegetation and land classification.....	(1/0/0)
5. The only realistic way to collect enough data to model and classify all the successional pathways is for management to be committed to collection of this data as part of their normal inventory and management.....	(0/0/1)
Subtotal - Part E.....	(3/6/7)
Grand total.....	(122/70/29)
<hr/>	
TOTAL R = RESEARCHERS (Scientists, classifiers, educators): 59	TOTAL RESPONSES: 221
TOTAL U = USERS (Managers and staff specialists): 34	TOTAL RESPONDENTS: 108
TOTAL N = NOT SPECIFIED: 15	

Applications--To develop applications for resource management, we are asking a lot of management specialists to go out and become ecologists and then link it together. Fortunately, managers and even scientists from other disciplines can learn to identify habitat types as a part of their routine field procedures. But, how do you pull all this information together? There are concepts and techniques that really have not been applied to this field. Methods that are used to summarize existing knowledge, such as Delphi or other group consensus techniques, may help meet the needs. New developments in the field of expert systems offer promise to help meet these needs. Is this a place for research to help meet these needs in an efficient manner?

Training--In regard to training, there is a real opportunity for educators, scientists, and management to jointly develop formal continuing education programs to meet the needs of the users. Several programs are in existence that should be continued and new cooperative education programs could be developed.

Similar thinking and planning needs to be applied to the other needs that are listed. However, expecting to receive a massive budget to meet all those needs that we listed is not really going to do it. It is going to come down to the concept of really wanting to see it happen--with professionals who want to do it, and other professionals providing the support to make it happen--not just saying that it is someone else's job. We all could have a hand in this.

There is a lot of work to be done. One person can not do it all. This symposium has been a demonstration of what a lot of people can do, even if not formally working together. The proceedings clearly demonstrates that we have come a long way. If we want to go further, if we really want to make this tool serve the end that foresters have agreed it could serve--not an end in itself, but as a means to an end--we must individually and

collectively use our own professional enthusiasm and influence toward that goal (and everyone here has professional influence).

The support for revising the Daubenmires' (1968) types came from a few habitat type users in Idaho, working on the ground, who said they would really like to see some of the broader types subdivided. That support came from a very few individuals who let that need be known through administrative channels to the point where the USDA Forest Service decided to finance it. This gave Cooper and others (1987) the opportunity to initiate sampling and make substantial improvement in the classification.

It has been really exciting to come back and see what has happened--to see how this program has grown--to see the constructive efforts to build upon existing foundations. I wish us well in meeting the challenges ahead.

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DOES A SYMPOSIUM HAVE AN AFTERLIFE?

THE COMMITTEE'S VIEW

Kenneth E. Neiman, Jr., and Kent E. Houston

ABSTRACT: The goal of this symposium was to bring together natural resource professionals from diverse fields of interest for the express purpose of discussing the current state of land classifications based on vegetation and their applications to resource management. The organizing committee perceived a need for interaction between resource managers and researchers and a need to reemphasize and refocus the direction of land classification studies. This paper summarizes the concerns of symposium speakers for current and future usage of vegetation-based classifications. A steering committee is proposed as a centralized coordinator for technology transfer and interagency research. Priority research/management projects are proposed for succession modeling, soil-plant community relationships, and effects of management practices on successional vegetation pathways.

INTRODUCTION

The purpose of this symposium was for the first time to bring together natural resource professionals from diverse fields of interest to discuss the state of western North American land classifications based on vegetation. We believed that a wide variety of applications were being used with only local dissemination of results and problems, thus limiting their effectiveness. Clearly, resource managers and researchers could benefit from exposure to recently completed and newly instituted empirical and theoretical research. We wanted to review the history of these land classification systems, the current status of development, and current applications in research and resource management. The gathering of interested parties for 3 days of discussion and mutually beneficial constructive criticism, though very worthwhile by itself, had a more important goal--the initiation of long-term ecological direction and coordination among land management organizations, academic institutions, and research units.

With the increased emphasis on multiple use of highly diverse resources, a common land classification

system would greatly facilitate communication, the extrapolation and exchange of data, and development of multidisciplinary management guidelines. The symposium committee deliberately arranged most of the sessions to have minimal specific subject orientation. The success of this approach illustrated one of the most important advantages of vegetation-based classification systems--they provide a common link or language between all natural resource disciplines.

Forty-three formal papers and 30 posters were presented at the symposium. There were 241 registrants, including resource managers, administrators, educators, and researchers from 18 States, British Columbia, and Alberta. Their interests and expertise encompassed the fields of forest, range, watershed and wildlife management, soil science, natural area conservation, ecosystem modeling, and other related fields.

CLASSIFICATION AND BIODIVERSITY

During the last 20 years, increasing emphasis has been directed toward protecting and maintaining biodiversity, not only in the United States but worldwide. A number of Federal and State acts give direction and emphasis to this activity in the United States. A knowledge of species, plant communities, and habitat requirements of plants and animals is essential for protection and maintenance of biodiversity. Inventories of plant and animal species, plant associations, and seral communities are used by Federal and State land management agencies, The Nature Conservancy, and State heritage programs to determine where to focus their efforts. Classification of climax plant associations and seral communities is essential to help explain species requirements and distribution. Development of plant association and seral community classifications and the appraisal of rarity and condition of species, plant associations, and seral communities provide a means for management to protect and maintain biodiversity.

One common problem with many recent classifications, primarily developed to aid land managers, is that they focus on "important" community types and often neglect rare and imperiled types. Because they are rare, some community types may have been missed or bypassed in the sampling from which the classification was developed. However, some classifications are noteworthy in their

Paper written for the Symposium "Land Classifications Based On Vegetation: Applications for Resource Management," Moscow, ID, November 17-19, 1987.

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attention to "very minor" and "incidental" communities. All who develop classifications should be encouraged to include not only the large and important but also rare and incidental community types. These latter communities may be in greatest need of protection and maintenance. Classification is the basis for identification, protection, and maintenance of biodiversity.

MAPPING AND INFORMATION STORAGE

Mapping of habitat types or plant associations is not merely the identification of land resource units, it is the development and recording of a basic understanding of the relationships between vegetation communities and their environment. At present there are no uniform standards for mapping habitat types or plant associations. Soil mapping has been a major project throughout the world and much can be learned from the techniques that have been refined over the years. Since soil and vegetation are both related to soil forming factors, it would appear that vegetation mapping techniques could use soil surveys as a template to develop and standardize methodology.

The advent of Geographic Information Systems and refinements in remote sensing techniques have revolutionized the storage, analyses, and uses of all forms of map data. Added to this is the computer storage of timber stand inventories, regeneration analyses, stand histories, current cover types, and numerous other stand characteristics needed for development of silvicultural prescriptions. These computerized data handling systems, when combined with artificial intelligence software that is being developed, will make highly sophisticated resource information and its analysis readily available to land managers.

TIMBER

Three equally important elements were originally envisioned in the development of vegetation-based land classification systems for the forests of the Intermountain West (Wellner, this proceedings). These same elements are also found to be of prime concern in all other vegetation-based classification projects being conducted throughout western North America. Habitat type or plant association classifications on a district-by-district or forest-by-forest basis, each developed by a different group of people having highly variable backgrounds in plant community ecology, has been demonstrated many times to be self-defeating. Therefore, the first task was the development by plant ecologists of classification systems based on climax or long-term stable plant communities occurring across broad geographic boundaries. This development of uniform classifications was given high priority because representative natural climax stands were becoming less frequent due to timber harvesting operations. The second element was production of secondary successional plant community classifications and stand development pathways. These would aid the prediction of plant community responses to disturbance and the

sequence of events over time following known treatments or natural disturbances. The third element was development of community-specific productivity, silvicultural, and other management implications. While many locally specific implications are known, their delineation and investigation have been random and there has been no systematic cataloging or dissemination of information.

A major component of the perceived need for this symposium was to develop a renewed interest in completing and continuing this three-part program. A major portion of the first approximation--baseline classification work for the western United States and Canada--has been completed. Second approximations based on increased data sets and improved analysis techniques are beginning to be published. Development of successional classifications has shown that further delineation of climax communities is both possible and desirable. An intensive program of successional classification is being conducted for the forests of central Idaho. But all other programs for updating primary successional or developing secondary successional classifications have been halted or are being conducted on a very limited basis. To increase efficiency and to be of the most benefit to resource managers, successional work should be performed in a unified manner over a large geographic area by highly qualified ecologists. The Intermountain Research Station, Forest Service, U.S. Department of Agriculture, program in central Idaho and the National Forest System's Regional Ecology programs of long-term, in-place Area or Forest ecologists should serve as models for conducting these studies. The commitment of personnel and money is not trivial, but the practical benefits are extremely large. The knowledge gained from successional classifications and silvicultural implications can generally be put into immediate use.

RANGE

Papers presented in the area of range resources reflected the general acceptance of the need for classification of ecosystem units as a basis for sound management. While classification of range vegetation is still weak in certain regions, there is evidence of accelerated progress during the past decade, due primarily to increased interest and support by the major land management agencies.

Differences in understanding the relationship of classification units such as series, habitat types, plant associations, ecological sites, or range sites, plus lack of information on seral vegetation as related to its climax state, were cited as examples of current problems in range-land classifications. Desire for a uniform system of classification was stressed, particularly by Bureau of Land Management representatives. The national soil classification system was cited as a potential model for such an endeavor.

TRAINING

Education and training of personnel involved with vegetation-based land classification systems is of considerable concern. A survey of professional foresters and forestry schools from the Far West revealed several significant points:

1. Field crews are not adequately trained to collect vegetation classification data.
2. A preponderance of bad data collected by poorly trained personnel is used in permanent forest inventory data bases.
3. Professional foresters and advisory staff both were judged weak in understanding the complexities of vegetation-based land classification systems.

Based on the survey results, there appeared to be a general feeling that all levels of the forestry profession lack sufficient understanding of the conceptual bases for vegetation-based land classifications, and thus their ability to interpret, extrapolate, and apply these classifications is seriously compromised. Both forestry students and agency personnel need more and better education in classification systems. Although they were not included in this survey, it is assumed that similar results would be found within the ranks of other natural resource disciplines.

WILDLIFE

Habitat relationships of many wildlife species are not keyed to plant community classifications based on floristics and site potential, but rather to stand characteristics such as stand structure, canopy closure, understory density, and other characteristics more indicative of available cover and forage. Nevertheless, a knowledge of site potential for plant species composition and quantity can aid in predicting stand characteristics that relate to wildlife habitat requirements. Investigations of climax/seral relationships must be expanded, since successional stages provide important forage and cover for a variety of species. Delineation of successional pathways within habitat types and plant associations should also be an important effort in wildlife habitat research and management. Efforts to relate habitat preferences to classifications of seral stages within habitat types will help in predicting effects of habitat change on wildlife populations.

RECOMMENDATIONS

In organizing the symposium, the committee found that the various disciplines are not significantly different in their approach to land classification. Converging most of these classification systems into one system seems reasonable and desirable. Terminology and classification systems should be standardized, at least for western North America.

Because of the complexity of interrelated studies and the need to integrate the efforts of managers with researchers within many of the studies, the

symposium committee believes that a steering committee should be instituted as a centralized coordinator of interagency land classification efforts. In addition to performing coordination of interagency research and monitoring administrative study overlap, this committee could facilitate technology transfer, act as a clearing house for the sharing of research results and management applications through symposia and workshops. This group could establish an information storage and retrieval system for land classification by vegetation, making it possible to highlight gaps in current information and serve as a guide for future investigations. Such a steering committee must be broadly based geographically and philosophically if it is to serve effectively. We believe there is a need for both a core group, which would perform the major functions of a steering committee, and a "loose" or oversight group, comprised of persons having widely dispersed professional and geographic backgrounds. Initially, the steering committee could be composed of interested people from the original symposium committee and other persons who would serve with them. This is not being proposed as a closed committee. Anyone desiring to participate will be more than welcome.

Many speakers at the symposium indicated a need for research projects in their area of interest. A conservative compilation of research and data analyses that are currently addressing these needs, or that need to be instituted, easily exceeds 50 projects. We suggest three subject areas for consideration as priority research/management projects: succession modeling, soil-plant community relationships, and effects of management practices on successional vegetation. Each of these subjects should be subdivided into multiple projects. All projects should be planned and conducted jointly by research and management personnel.

At least 16 papers and posters dealing directly with secondary succession processes or modeling efforts were presented at this symposium. The one consistent trait in most current models is the narrow applicability as to geographic region and group of plant associations described, or subject area of use (such as silviculture, wildlife habitat, or fire management). High priority should be assigned to additional successional community classification and modeling projects. The amount of data collection and analysis needed to provide successional classifications for only the most prevalent and economically important plant associations occurring throughout the western United States, British Columbia, and Alberta would keep many teams of ecologists busy for years to come. We also find that, although many succession models have been developed recently, few of them have undergone intensive field verification by qualified ecologists. Feedback to researchers has primarily been from satisfied users; managers who try the model and find it wanting, simply abandon its use.

Similar to the interest in succession modeling, a need for soil-plant community relationship studies was discussed. One formal paper and three posters

dealt directly with this subject, while a dozen or more of the papers and posters focused attention on the need for baseline data and research. Several speakers recounted observations of variable successional responses to application of the same silvicultural prescription within a single habitat type or plant association. The only difference they could account for between sites was in the soil supporting the communities. Research projects should be developed that determine the relationship within or between soils and plant communities, and that determine if these relationships have management significance. It is our opinion also that plant community and soil resource classifications should be developed concurrently. The resulting baseline data and classifications would be far more useful and precise than those developed independently.

The third area we feel should have a high priority is the compilation of plant community responses to specific management practices. Where classification systems are too recent for this information to be readily available, documentation and studies of the effects of management practices on successional vegetation should be implemented. Although studies in this subject area run parallel to the succession modeling discussed above, we feel that separate projects are needed with emphasis directed toward identifying community responses to specific kinds and degrees of management applications under varying site conditions. We view this project as requiring an applied research approach rather than the more conceptual emphasis needed in computer modeling of succession. This group of studies is one in which resource managers must participate from the beginning and at a level of personnel involvement not previously afforded managers due to the research nature of the project.

A major effort should be made to develop closer links between researchers and field management personnel. At present the gap between available research data and their utilization seems wide, and it is not being fully bridged by conventional extension efforts. To more efficiently conduct

long-term cooperative studies, changes should be instituted in Federal and State agency regulations governing the direct involvement of resource managers and the use of management funds for what are ostensibly research purposes.

CONCLUSIONS

We feel a truly successful symposium must have an afterlife. To this end, we recommend that a committee be formed to begin the task of coordinating technology transfer through additional symposia, workshops, and literature distribution and to coordinate research related to habitat types and plant associations. This effort must be extended to all concerned parties through their participation, not just through a restricted group of interested individuals. Greater emphasis is needed on field-oriented workshops and short courses in which interested user groups can focus on the underlying conceptual basis as well as the applications of classifications of specific wildland ecosystems.

A number of studies should be developed, funded, and completed if management's need for successional information is to be met in a timely manner. Plant ecologists should conduct the required studies with a committed, formal participation of resource managers. Studies conducted through cooperative efforts of researchers and managers would achieve results more quickly and would generally be more readily accepted and used by natural resource managers.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the members of the symposium committee listed in the foreword of these proceedings for their contributions to and critiques of this paper, and for their generous contribution of time, effort, and ideas in the creation and execution of this symposium.

POSTER PAPERS

**Synopses of 24 Posters
Shown at the Symposium**

ECOLOGICAL LAND CLASSIFICATION IN CANADIAN ROCKY MOUNTAIN NATIONAL PARKS

Peter L. Achuff

Ecological Land Classification is an integrated resource inventory method which uses landform, soils, vegetation and wildlife information presented in both report and 1:50,000 map form. These land classifications have been prepared for the six Canadian Rocky Mountain National Parks of Banff and Jasper (Holland and Coen 1982), Kootenay (Achuff and others 1984a), Mount Revelstoke and Glacier (Achuff and others 1984b) and Yoho (Coen and Kuchar 1982). A three-level, hierarchical land classification was developed using the Canadian landform and soils classification systems plus a vegetation type classification developed by project scientists. The three levels, from highest to lowest level of generalization, are: Ecoregion, Ecosession and Ecosite.

Ecoregion separations are based primarily on vegetation physiognomy and species composition which reflect macroclimate. Montane, Subalpine and Alpine Ecoregions are recognized. The Subalpine Ecoregion is divided into Lower Subalpine and Upper Subalpine based on vegetational characteristics reflecting macroclimatic differences.

Ecoregions are divided into Ecosessions based on broad landform, drainage class and soil differences. Landforms are composed of ten genetic materials which are divided into genetic material units based on textural and chemical (calcareousness/pH) differences. Ecosessions are divided into Ecosites based on landform, soil and vegetational differences of smaller magnitude than those used at the Ecosession level. Ecosites plus nine Miscellaneous Landscapes (for example, colluvial landslide, rock glacier) are the map units delineated. The landform, soil, vegetation and wildlife characteristics of each Ecosite are described in the reports and map legends. Wildlife information includes the importance of each Ecosite for common animals and descriptions of breeding bird communities and small mammal associations, as well as species and watershed area accounts (Holroyd and Van Tighem 1983; Poll and others 1984; Van Tighem and Gyug 1984). Importance ratings for wildlife in each Ecosite were derived from field data on actual use (for example, from pellet counts and browse use ratings for ungulates or call count transects for breeding birds) rather than by inference from habitat features.

Poster presented at the Symposium on Land Classification Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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Ecological Land Classifications have been used successfully for a variety of planning and management purposes including: environmental impact assessment and monitoring, fire management, facility planning, forest insect and disease management, trail location, rare species management, archaeological research, range management for both wild and domestic species, and bear/habitat evaluation and management.

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FEDERAL AND STATE ECOLOGICAL SITE CLASSIFICATION:

TWO APPROACHES WITH COMMON GOALS

Barbara H. Allen and David V. Diaz

ABSTRACT: Ecological site classification is being conducted by the California Department of Forestry and USDA Forest Service in California. Although these agencies have similar goals, their approaches are very different. The Forest Service' focus is to classify all vegetation on National Forest System lands, while the State's focus is hardwood rangeland of all ownerships. The Federal effort involves on-the-ground specialists collecting new information and developing the classification over 3 to 7 years, while the State effort focuses on the use of existing plot data to develop an ecologically based cover type classification system in 18 months. Goals, objectives, approaches, and expected products are described.

INTRODUCTION

Classifications are tools for organizing, labeling, storing, and retrieving various kinds of data. Ecological classifications are particularly useful in resource management because they integrate diverse attributes of vegetation, soils, and landforms into homogeneous areas. These areas are united by complex ecological inter-relationships and common predictable responses to management inputs. The process of developing these classifications most often involves the collection of environmental and vegetation data over specific geographic targeted areas. The process also involves the commitment of skilled ecologists to become intimately familiar with the ecosystems being studied. The results are detailed site-specific descriptions for areas bound together by common vegetation, soil(s), landform(s), productivity, and expected response to management. For managers, the results are a common language for describing land and specific information for improving management decision making.

Poster presented at the Land Classifications Based on Vegetation: Applications for Resource Management Symposium, Moscow, ID, November 17-19, 1987.

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THE PROBLEM

The development of an ecological type classification system by the Forest Service in California began in 1983. Prior to this time several factors worked against the development including (1) a perceived lack of need, (2) a belief that California's vegetation was too diverse and complex, and (3) an aborted and expensive effort attempting to do ecological type classification which discouraged managers.

By 1983, the USDA Forest Service in Region 5 was five years into Forest Land Management planning required by recent Congressional mandate. The agency's managers were intimately aware of the difficulties arising from being restricted to using uncommon land labeling systems, uncommon inventory units, and predictive information that was not ecologically based. These data were essential for planning models such as FORPLAN and to develop site prescriptions where resource demands increasingly conflicted and personnel, unfamiliar with the ecosystems, were forced to make management decisions. The days of depending on a person's 30 years of familiarity with a particular place were rapidly disappearing. These factors led to the initiation of an ecologically based land classification program in the Region in 1983, by appointing a Regional Ecologist program leader, who was to be guided by an interdisciplinary resource advisory committee.

Meanwhile, resource personnel working for the California Department of Forestry (CDF) watched the Forest Service classification effort with interest, keeping informed of the effort through participation in a coordinating group called the Interagency Vegetation Classification Committee. During this time, the State's Forest and Rangeland Resource Assessment and Planning staff (FRAAP) was preparing a statewide assessment of natural resources. Common problems with lack of common labeling systems, lack of compatible inventory data, and lack of research information on site response to management made State managers fully aware of the need for an ecologically based classification.

During the period that FRAAP was making its assessment, the management of the State's hardwood rangelands, which occupy approximately 3 million hectares in California, spread over 52 of 58 counties, became a land use issue and the focus of much attention from the State Board of Forestry, private ranchers, and resource and environmental groups. Rapid population growth in

California has caused hardwood rangeland conversion from open space to housing and agriculture, loss of wildlife habitat, and an increased cutting for fuelwood. This, coupled with documented hardwood species regeneration problems, the lack of a unifying classification or descriptions of hardwood site potentials, and an immediate threat of State-imposed regulations on the use of the hardwood resource, 85 percent of which is in private ownership, moved the State to establish an Integrated Hardwood Management Program. The Program is designed to develop, administer, and monitor research, education, and technology programs to improve knowledge of the hardwood resource. The development of a hardwood ecological site classification system was one such funded research project.

GOALS AND OBJECTIVES

Thus the Forest Service and State of California had fundamentally similar problems and common goals for the development of an ecological classification system. The goals can be summarized as:

1. Improve communication among resource managers through use of a common labeling system and site descriptions;
2. provide unifying framework for the organization of other classifications, inventory, and mapping systems; and
3. improve the information available for the resource managers' decision making, giving them predictive ecological information.

Objectives of the two agencies differ only slightly. The Forest Service effort focuses on all National Forest System lands in California including the development of ecological type classification for all vegetation types. The classification is expected to link diverse resource inventories and provide baseline information for future Forest Land Management Planning and RPA Assessments. The Forest Service plans to develop seral stage descriptions, provide information on site response to management, and develop methods to determine ecological status and resource rating guides. The State and the Forest Service want to increase the application of theoretical and applied research results through the use of the ecological site classification.

The State's focus is on all state, federal and privately owned hardwood rangelands. The development of the classification will assess available ecological and management information, provide for a statewide hardwood rangeland data base, and establish methodology for refinement and field testing, and future evaluation.

APPROACHES

The Forest Service and State approaches to the development of the ecological site classification are quite different. The Forest Service is collecting new site-specific data in two phases, a reconnaissance phase of approximately 3-4 years

followed by an intensive phase of another 5 to 7 years (fig. 1). This two-phase strategy evolved after review of existing plant community and habitat type approaches used in other parts of the country and with input from resource specialists in the Forest Service. The approach stresses detailed field data collection and intimate resource familiarity by an ecologist/soil scientist team. Resource manager review of products is an integral part of the process.

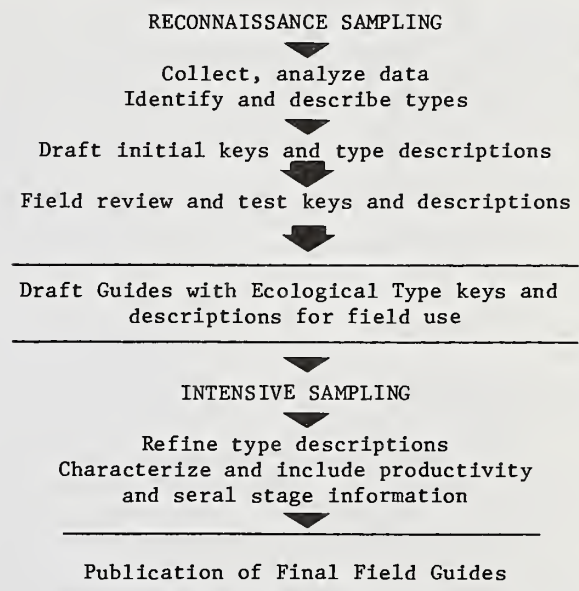


Figure 1--The six major steps in the development of the Forest Service Ecological Type classification system are carried out by a team of ecologists, botanists, and soil scientists.

The State approach took the form of a contract awarded by CDF to the University of California, Berkeley. By agreement, the ecological site descriptions for the hardwood rangeland resource must be completed in 18 months. The timeframe necessitates the use of available plot data collected in California by different agencies over the last 30 years. Three data sets will be used: the Pacific Northwest Station Forest Inventory data, the California Soil/Veg Survey data and the Soil Conservation Service Range Site data. A public workshop scheduled for winter 1987 will provide the forum for reaching consensus on classification criteria. Site descriptions will be developed for field testing by resource experts. Hammon, Jensen, and Wallen, an Oakland-based environmental consulting firm, will develop methodology for computerizing the classification descriptions and mapping classification units.

PRODUCTS

Forest Service ecological type descriptions, in draft stage at present, contain information on the vegetation, landforms, and soils. When

completed they will provide productivity of the site for different resource uses; expected site response to management, such as fire, grazing and timber harvesting; seral plant communities; and relationships to other ecological types. At a site location, the information will be accessed through the use of a dichotomous key. Sites will be identified in the field through knowledge of a few indicator plants and use of the dichotomous key. A representative photograph of each site will be included in the field guides.

The State hardwood descriptions will be broader, limited by the kind of plot data used in their development. Because the data in the three data sets were collected by different and independent investigators, it will be difficult to dis-

tinguish potential natural vegetation from seral stage plant communities. Although the focus is on mature hardwood stands, the type of data and the short timeframe for field testing seem to require the use of the term "cover type" until further evaluation proves the successional placement of a type. Information on response to management and predicted seral plant communities will come from past and current research, where the research unit was labeled with this system's identified types. Future research and the Forest Service ecological type work in the hardwood rangelands with National Forests will provide additional information to refine and update the State's hardwood rangeland classification. A photograph, representative of each site, will be included with the description.

A MULTILEVEL RESOURCE INFORMATION SYSTEM USED AT THE FLATHEAD NATIONAL FOREST

Stan Bain

ABSTRACT: Flathead National Forest encompasses approximately 2.6 million acres in northwest Montana with Forest headquarters in Kalispell. Flathead National Forest is confronted with the problem of managing an area with diverse concerns. With the increasing pressures to provide better management of Forest resources with reduced budget and to balance the needs of timber, wildlife, and recreation in an economically and ecologically sound manner, it is increasingly important that map and tabular information be available to resource managers in an efficient manner. Flathead National Forest has adopted the use of Geographic Information System and Image Processing technology along with Remote Sensing using Landsat data, to construct a Multilevel Resource Information System as one means of supplying information in a timely and economical fashion.

INTRODUCTION

The combination of computer-assisted Geographic Information System (GIS) and Remote Sensing (RS) satellite data provides spatial overlays necessary for analyzing multiple layers of information. The GIS produces results in minutes, whereas conventional methods of making overlays and maps for analysis may take weeks, months, and years to complete. GIS uses digital data in coordinate form to produce data planes (layers) which are maintained in the system as individual databases. Through computer manipulation, any number of planes may be combined with assigned parameters to produce a variety of map and tabular results. The speed and power of computer manipulation is especially valuable for sensitivity testing in the iterative process of alternative generation.

Establishing in-house GIS and Image Processing (IP) expertise and maintaining in-agency project management were identified as vital success factors in creating an operational Multilevel Resource Information System (MURIS) program. Flathead National Forest (FNF) personnel were trained in GIS and IP system use through the

Digital Image Analysis Laboratory at Washington State University Computing Service Center (WSUCSC). Throughout the project, GIS and IP have been performed with WSUCSC's VICAR/IBIS image processing system via telecommunication from FNF agency office. VICAR/IBIS provides many processing alternatives for combining, overlaying, and analyzing multiple raster-formatted data planes, using image processing algorithms to manipulate spatial data mathematically.

THE FNF OPERATION

This MURIS effort is unique in two respects: the FNF has not acquired any additional computer hardware or software to reach the present operational stage; and, FNF personnel have performed all project work rather than having the project contracted to an outside service organization. In the future some of the basic digitizing may be contracted under direct supervision of Forest personnel, as the major work of digitizing must be done at the Forest level to ensure fully developed diversified data planes. The Landsat classification, map digitization, data management, project implementation, coordination and applications through data plane manipulation were done by Forest personnel. As the database for each ranger district reaches the operational stage, personnel at the ranger district receive training in data plane combination and query techniques enabling data manipulation capabilities at the ranger district office. Additional capabilities will need to be added to the present computer facility at Forest headquarters to display and optimize MURIS capabilities.

When MURIS was evaluated by Forest managers, speed and accuracy of GIS and IP product generation met all acceptability criteria. Operational MURIS databases are now being constructed and the completion of Landsat classification and ground correlation will be completed next year for the Forest in its entirety.

APPLICATION CATEGORIES

In the operational phase of the MURIS, applications fall under three basic categories; inventory, modeling, and monitoring. The Landsat classification, with the recent refinement, satisfies the need for a plant community map. The convenient quantification of area and length

Poster presented at the symposium Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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provides needed inventories for surface waters, roads, trails, and other data planes. When digitally overlain, multiple data planes can be applied to inventory site-specific parameters, such as the distribution and abundance of grizzly bear food types within a particular drainage. Derivative inventory data can also be produced from original inventory planes. These data planes contribute a comparative means to address questions of human influence on the environment and wildlife.

These simple inventories provide the bases for modeling efforts that involve manipulation of multiple data planes. Modeling potential elk calving location is critical to management of that species. Other modeling techniques are fire behavior modeling, modeling erosion impacts, identification of trail hazards, modeling trail and campsite locations, and timber stand inventories and others.

Each geographic plane, whether derived through inventory or modeling, serves as a baseline by which changes can be detected and measured in the future. Monitoring further serves to test hypotheses and the validity of models over time. Monitoring will also provide an understanding of long-term natural processes such as plant succession after fire and the progression of widespread forest pathogens.

THE FUTURE

Our goal is to continue with our relationship with WSUCSC in further Landsat classification and to provide a in-house GIS and display system for analyzing alternatives. Applying a full range of application from the Forest, MURIS will allow planners and managers to analyze alternatives on critical lands where vegetative manipulation and other project proposals can achieve the desired objectives of land management economies and efficiencies.

LANDSAT CLASSIFICATION AND FIELD CORRELATION METHODS FOR VEGETATION
CLASSIFICATION USED AT THE FLATHEAD NATIONAL FOREST

Stan Bain

ABSTRACT: Landsat, one of the most important achievements of the U.S. space program, has the capability to perform inexpensive world-wide surveys of global conditions and resources. But Landsat alone cannot achieve resource survey without support data from other technologies such as Geographic Information System (GIS) technology, as well as accurate location of field plots and field data. A multiclustering technique with an intensive spectral analysis and editing method is performed to provide a statistics set for a spectral classification. With the use of field data, a strata requirement is formulated to use other spatial data planes to correlate field data to the Landsat spectral classification. With the spectral classification and the formulation of other spatial data planes, a detailed vegetation Landsat classification is performed. With support technology, capabilities, and correlation with field data, Landsat can provide an accurate, economical, and efficient method for mapping vegetation for a wide range of management applications.

INTRODUCTION

There are several very important steps to accurately map resource information to the level of most project applications from Landsat data. In our approach, the analysis is made using VICAR/IBIS (Video Image Communication And Retrieval, Image Based Information System) (Hart and Wherry 1984), at Washington State University Computing Service Center (WSUCSC) as the primary processing system. VICAR/IBIS, a batch processing system, with localization of the input/output operation and with many parameters, provides many processing alternatives. The IBIS extension to VICAR adds significant capabilities for combining, overlaying and analyzing multiple data sets, which is critical to this project. The raster format data can be spatially manipulated mathematically using digital image processing algorithms (Jaffray and others 1984) in the classification of spectral data.

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METHODOLOGY

In this project a methodology similar to the multiclustering technique described by Hoffer (1979) was used with a few modifications in the construction of the final classification statistics set. This guided clustering methodology is basically a supervised approach with one very important modification: unsupervised clustering is done within small training areas to reduce spectral nonuniformity within the final classes. Essentially the same procedure is used in a supervised approach in selecting training areas. Some care needs to be taken to ensure spectral purity where possible to make fine distinctions with the Landsat data between species. Each training area will produce several spectral classes in a statistics file. Several statistical files will contain several hundred sets of statistics which need to be edited and combined into one statistical file for classification.

The analysis of the statistics and the final statistics set will make or break the final vegetative classification. It is very important in the analysis of the statistics, especially in the timber areas, to keep the covariance as small as possible, to only pool clusters that are exactly the same, and to not pool clusters that have a small covariance with clusters with large covariance. All spectral classes must be compared with spectral separability of other spectral classes, and by analyzing the covariance and the separability, the confused classes can then be deleted in the editing process. Spectral plots between MSS band 5 and MSS band 7 will aid in this editing process. A scatter plot showing pixel populations in a three-dimensional scatter diagram is very helpful to ensure that the final statistics will cover the full range of spectral data when compared to the spectral plot. The final statistics set may contain as many as 80-140+ statistics to be used in the final spectral classification. Remember when doing a Landsat classification you are mapping spectral data and not vegetative data.

Once the spectral classification is complete, the image is registered to a UTM (Universal Transverse Mercator) map projection. This is done by selecting several control points, lines, and samples on the image and corresponding points on USGS 7 1/2 minute quad by using International Imaging System, a system 511 image display system at WSUCSC. Map control points are digitized to determine the UTM values of each point.

Control points are evaluated and those in error are edited out until a residual of less than one pixel is obtained. Using the control point file, a geometric transformation is performed registering the Landsat spectral classification to UTM, 50 meter pixel image. This image is now registered to other data planes that will be used in the final stratified classification.

It is also very important to be able to correlate ground plots with the spectral data. In doing so, the ground crews must be able to accurately locate the field plot within the spectral class. This is done after the spectral classification is completed. Flathead National Forest (FNF) personnel use the following procedure to produce a spectral map at a scale of 1:15840, sometimes referred to as a lineprinter map. Spectral classes of 6 pixels or greater are located on the spectral map to form spectral polygons. These polygons are then transferred to orthophoto maps, or aerial photography by stereo compilation methods. FNF personnel and contractors use the orthophoto maps and aerial photography products to locate their field plot within or close to the center of the spectral polygon. Basic photo interpretation techniques are used to measure the bearings and distances from a starting point or image point on the photo products to locate oneself within the spectral polygon.

Several plots are taken of each spectral class representing major elevation, aspect, and ecological relationships. A one-tenth-acre plot is taken that will represent the vegetation of the spectral polygon. Sometimes a "walk through" of the spectral polygon is performed before the plot location is determined to ensure the plot location will represent the spectral polygon. The walk

through may reveal that more than one plot needs to be taken in the same spectral polygon to map the major difference in the vegetation. Within the plot location all vegetation is measured and timber stand data is recorded as well as other environmental features that will aid in the stratified classification of a confused spectral class.

All field data and spectral classes are entered into a data entry program on the Forest computer system. Through data analysis, Forest personnel can determine stratified requirements for each spectral class or classes and whether elevation, aspect, soils, etc. is needed to classify the spectral data into vegetative data for final classification (table 1).

A series of data planes may be needed to meet the stratified requirements. Elevation, aspect, and soils were mentioned above, but requirements may also include other spatial data. Not all of the spatial data planes need to be used for each spectral class. As an example, spectral class 1 may require only elevation zones to clarify the confusion of a vegetation class, or it may require several data planes to accomplish the task. Even a spectral class at a specific elevation zone and aspect may be combined to another spectral class on a specific soil type and aspect to make an information vegetation class.

Once the stratified requirements are determined for each spectral class, a computer job is set up using Geographic Information System (GIS) technology or look-up tables to classify the spectral data into a vegetation classification. This result can provide a very detailed legend and

Table 1--Spectral class and strata report

SPECTRAL CLASS	ELEV	ASP	SLOPE	HT	STC	FCC	SP1	%	SP2	%	SP3	%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
12	4000	S	10	450	SEED	0-10	PICO	10	PSME	10	XETE	40
12	4200	NE	35	690	SEED+	0-10	PICO	10	LAOC	30	ABLA	10
12	5900	SE	60	691	SAP	71-100	PICO	50	PSME	10	ABLA	10
12	6300	E	90	691	SAP	41-70	PICO	50	PIAL	10	ABLA	10
12	7000	SW	30		SEED+	11-40	ABLA	20	PIAL	10	XETE	60
13	3800	E	20	662	SAP	41-70	PICO	50	ABLA	20	PIEN	10
13	3800	W	50	662	SAP	41-70	PICO-10	PIEN	30	PSME	20	
13	4000	NE	0	663	POLE	41-70	PICO	20	LAOC	20	VASC	20
13	4000	NE	40	662	POLE	41-70	PICO	40	LAOC	30	VASC	20
13	4000	W	10	640	POLE	41-70	PICO	40	PSME	10	ABLA	10
13	4000	W	10	640	POLE	41-70	PICO	40	PSME	10	ABLA	10
39	4000	W	50	623	MATURE	71-100	PICO	30	LAOC	30	PSME	30
39	4000	W	80	691	MATURE	41-70	PICO	40	LAOC	10	PSME	10
39	4300	N	35	624	OLD	41-70	PICO	50	LAOC	10	PIEN	10
39	4600	SW	25	653	MATURE	41-70	PSME	40	LAOC	10	PIEN	10
83	3600	W	20	750	POLE	11-40	PICO	40	LAOC	10	CARU	70
83	6900	NW	20	850	POLE	11-40	PIAL	10	ABLA	20	PIEN	10

(1) spectral class from landsat classification, (2) elevation
 (3) aspect, (4) slope %, (5) habitat type, (6) structural class, i.e.
 seedling, mature, old growth, etc., (7) forest canopy closure %, (8) thru (10) vegetation species.

Table 2--Landsat vegetation legend

VEG CLASS (1)	DESCRIP. (2)	SP1 (3)	SP2 (4)	SP3 (5)	SP4 (6)	SP5 (7)	ST (8)	FCC (9)	HAB (10)	CLASS/ACC (11)
1	WATER									90-100
12	AGG	CROPS								90-100
33	CONIFER	PICO	LAOC	PIMO	VAGL	XETE	OLD	11-40	6	85+
36	CONIFER	PICO	PSME	PIEN			MAT	11-40	5	80+
54	SHRUB/CONF	ACGL	ALSI	LOAC	PIEN	ABLA	MAT	0-10	6	85+
185	HERBAC	SOIL	GRASS	PICO			SAP	0-10	6	85+
190	NON-VEG	ROCK	SOIL				N/A	N/A	N/A	90-100

(1) Vegetation class, (2) Cover type, (3)-(7) Species by dominance, (8) Structure; mature timber, old growth, etc., (9) Forest canopy closure %, (10) Habitat group, (11) Vegetation class accuracy determine by field plot, photo interpretation

classification then can be used for a wide variety of resource applications (table 2). This process can provide information such as species in order of dominance, crown density, and structure, as well as quantitative information.

VERIFICATION AND ACCURACY CHECKS

Verification and accuracy assessments are often required to achieve a predetermined level of accuracy; at the very least, users will want to know the level of accuracy associated with the finished classification so that they will understand how best to use it. With the use of this method of classification and ground correlation, the accuracy of the project can almost be determined or built into the classification process itself. Sometimes the confused spectral classes may require additional field plots or other stratified requirements to achieve the accuracy one requires.

Ultimately, a verification is needed to provide a degree of confidence and reliability in the classification. FNF uses several steps in checking the accuracy of the classification process. Each field plot, that was taken inside the spectral polygon is digitized and converted to an image. This image can then be overlaid on the final classification to check to ensure that the stratified requirements were met, and the field plot description correlates with the vegetation classification description. The system 511 at WSUCSC is used by displaying 512x512 images of the classification and visually checking the overall classification with aerial photos, timber stand maps, and other mapping records. Classes that are questionable are checked on the ground with a walk-through method or with additional ground plots if additional classification work is needed. Errors are corrected if project accuracy of 80 percent is not met. Accuracy level is assigned to each class which becomes part of the final legend (table 2). As the vegetative classification is used for application, such as in wildlife habitat mapping, fire group classes, or mapping old growth timber, the individual vegetative classes are combined into a cover class which greatly increases the accuracy.

CONCLUSION

With accurate field plot locations, and accurate field data, along with intensive cluster and spectral analysis and correlation, Landsat can provide a vegetation classification. The classification results can provide resource managers a GIS vegetation data plane containing species, forest canopy closures, habitat type groups, structure, and quantitative information such as timber volumes.

Landsat classification with GIS technology can provide forest managers vegetative information that managers can use in the analysis of Forest resources of timber, wildlife, fire management, and recreation in a economical and efficient method. This method, with a temporal Landsat classification, can monitor changes due to timber sales, plant succession after fire, and the progression of wide-spread forest pathogens. This system will provide important information to FNF to meet its management mandate and administer its Forest Plan (Proposed Forest Plan 1983).

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A VEGETATION CONDITION APPROACH TO LAND USE PLANNING

R. Lee Barkow

ABSTRACT: Land use planning can be accomplished effectively by focusing on the vegetation condition necessary to produce the desired commodities or values. This planning process utilizes the difference between current and desired vegetation conditions and related productivity to identify opportunities for change. Successful land use planning will develop a strategy that will assist managers in moving from the current vegetation condition toward the desired condition.

INTRODUCTION

The purpose of land use planning is to make decisions that will accommodate various land uses and direct the management of a particular area. In doing so, it is important to accurately identify the proposed uses, the possible conflicts in accommodating each of the uses within a particular area, and develop alternatives to resolve the conflicts. Conflicts, either real or perceived, are the heart of all planning systems. Issues are usually portrayed by managers and the public alike as two or more land uses or values which appear to conflict within an area. Issues such as a conflict between livestock grazing and wildlife, and mineral development and recreation are common to most land use plans. When an issue is identified, the most common response is that there is in fact a conflict because the competing uses need the same resource base to sustain each use. There is not enough of a resource or land to go around. Conflict resolution usually revolves around selecting one use over the other or splitting the available land or resource between the competing uses. There is little attention or thought given to identifying what it would take to accommodate the competing uses in terms of describing the resource needed to accommodate all of the demand.

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VEGETATION CONDITION CLASSES

When we, as professional land managers, and the public look at a given area, the first element of the environment that we focus on is the condition of the vegetation. We often make statements that relate to either the current condition of the vegetation resource or the desired condition of the vegetation which is different from the current condition. For instance, when we look at the quality of the water present, whether it is in a lake or a perennial stream, we often relate it to the condition of the vegetation within the drainage or watershed. We may identify a high sediment load and trace the cause to overgrazing, overcutting, or poor riparian vegetation.

Most proposed land uses or values can be placed within an identified vegetation condition that is optimum for the desired use. For instance, we can describe the optimum condition for winter range or escape cover for target wildlife species. We can describe the optimum vegetation condition for livestock grazing at various stocking levels. In addition, we can describe the optimum vegetation conditions for such activities as off-road vehicle use, dispersed recreation, and scenic quality. Granted, the optimum vegetation conditions are not the same for all activities or uses. But the point is that we can describe the desired vegetation condition for most proposed uses.

Similarly, we can describe the current condition of the vegetation and add it to the amount of activity or use that the vegetation is supporting. With this information, the difference between the current condition and the desired condition can be determined in straightforward terms.

RELATIONSHIP WITH CURRENT PLANNING PROCESSES

Planning from the perspective of a vegetation condition is easily accommodated within most current planning processes. The only requirement is to do some steps in a slightly different order. The following explores how this could work.

The first step in this planning process is to describe the current vegetation condition and the related productivity for each commodity resource or value for each non-commodity

resource. This step will create the base condition from which change will be measured. It will be important to accurately describe the productivity of the area and tie it to the vegetation condition. If the productivity is due to some factor other than the vegetation, this fact must be understood from the beginning because a change in the vegetation would not increase the productivity.

It is also important to identify those resources or uses that are not dependent on a particular vegetation condition so that they can be considered in subsequent steps. This would include such activities as oil and gas development, coal development, and float boating.

The next step in the process is to describe the desired vegetation condition and related productivity for each commodity resource or value of each non-commodity resource. It is likewise important to be able to accurately link the increase in productivity or value of the resource to the vegetation condition. If it is not known how productivity relates to the vegetation condition, then it is not possible to describe the desired vegetation condition to ensure that the productivity or value is realized.

The difference between the current vegetation condition and the related productivity or value and the desired vegetation condition and the related productivity or value can be considered the "opportunity for change" or "opportunity value." The objective of this planning process is to move from the current condition to the desired condition. The success of the plan can be measured in terms of the amount of the opportunity value that is being realized at any point in time.

The next stop is to determine if the planning area has the biological capability to achieve the desired vegetation condition and related productivity or value that has been previously identified. In many instances, some productivity or resource value may have to be adjusted or accommodated over time to be compatible with the biological capability of the planning area. When the planning area cannot produce all of the desired units or values, then the difference between desired productivity and potential productivity is considered to be a "planning issue" that needs to be addressed in the subsequent alternative discussion.

To summarize the planning process at this point, we have identified:

1. The current vegetation condition and related productivity;
2. The desired vegetation condition and related productivity;
3. The opportunity value;
4. The biological capability of the planning unit;

5. The difference between the desired condition and the biological capability.

The next step in the planning process is to identify what the minimum acceptable productivity or value will be for all resources or values. All minimum acceptable productivity or values must be achievable within the planning unit and must be able to be accommodated in each alternative that is developed. These minimums guarantee that a certain level of productivity or resource value will be realized no matter what alternative is finally selected. The next step in the process is to develop alternatives to resolve the issues. Alternatives are the different ways to accomplish the same objective. All too often, land use plans confuse alternatives with options. Options are different objectives that can be met but they do not necessarily achieve the same objective. Alternatives in land use plans often use words such as "environmental alternative" or "commodity alternative" or "multiple use alternative" or some similar words. It sounds like each alternative is exclusive of each other. It appears that, if a commodity alternative is selected, sound environmental management will not occur. Or if an environmental alternative is selected, multiple-use management will not occur. Adversarial positions are developed among the various publics by the names that are given to the various alternatives.

Using alternatives in the proper sense does not require placing arbitrary names on each one. Since the objective is the same for each alternative, then none are "environmental" or "production" alternatives. The difference between alternatives is properly focused on the amount of opportunity value that is achieved. The vegetation condition and the relative productivity or value allows all interested publics to review a draft plan and comment on the various alternatives using the same basis. Comments can now be focused on the success of each alternative in achieving the opportunity value. Differences of opinion can be focused on something that can be addressed in re-analysis rather than differences relating to entirely different objectives. When there is no opportunity for change or if the planning area can completely accommodate the desired vegetation condition, productivity, or value, then there is no need to debate the issue unless there are opinions that affect the condition, production, or value.

A preferred alternative is selected that best meets the desired vegetation condition class and related productivity or value and meets the minimum acceptable levels identified for each resource.

The final step in the planning process is to select the final plan for the unit and begin implementation. An activity can be allowed within a particular area as long as the stated vegetation conditions can be realized and the productivity or value is achieved. If the

proposal interferes with meeting the objective, then the proposal is rejected or a change in the stated vegetation condition is made through a plan amendment.

SUMMARY OF THE PLANNING STEPS

The ten steps in the planning system described above are:

1. Identify the current vegetation condition and related productivity.
2. Identify the desired vegetation condition and related productivity.
3. Determine the difference between the current and desired condition and related productivity (opportunity value).
4. Determine the biological capability of the planning unit.
5. Determine the opportunity for change in terms of either vegetation or productivity (desired minus current condition).

6. Where an area cannot achieve all of the desired vegetation conditions or productivity, a planning decision must be made (planning issue).

7. Criteria are developed to resolve the issue. These state what is the minimum acceptable condition.

8. Alternatives are developed to achieve the desired results, while meeting the minimum acceptable level for each resource.

9. A preferred alternative is selected that best meets the desired vegetation condition and related productivity and meets the minimum acceptable level for all resources.

10. A final decision is made and the plan is ready for implementation.

CONCLUSION

Land use plans developed using a vegetation condition approach would improve comparability and would serve the resource manager and public well in developing management objectives and in constructing a course of action that would guide changes in the vegetation condition from their current condition towards a desired condition.

VALUE OF "FIRE ECOLOGY OF WESTERN MONTANA FOREST HABITAT TYPES"

TO RESOURCE MANAGERS

Anne F. Bradley

ABSTRACT: The publication "Fire Ecology of Western Montana Forest Habitat Types" presents generalized, multiple-pathway models of postfire succession for 11 "Fire Groups." Each fire group is composed of coniferous forest habitat types with a similar fire response. The groupings are intended to help managers understand how potential vegetation, fire severity, and stage of community development influence fire effects.

Classification based on potential vegetation can be used as a framework to summarize our current understanding of fire's natural role in forest succession. It can also help land managers determine whether fire is an appropriate tool to meet particular objectives. The recent publication "Fire Ecology of Western Montana Forest Habitat Types" (Fischer and Bradley 1987) is an application of classification to forest management. This document complements an earlier publication, "Fire Ecology of Montana Forest Habitat Types East of the Continental Divide" (Fischer and Clayton 1983).

In this fire ecology publication, habitat types are assigned to "Fire Groups" based on the response of dominant tree species to fire and the role these species take in forest succession. The description for each fire group includes information on forest fuels, the natural role of fire, plant community succession, and fire management considerations. Community succession is illustrated by multiple-pathway models (see fig. 1). These are modifications of earlier models describing how individual species' attributes affect the successional process (Kessell and Fischer 1981; Noble and Slatyer 1977, 1980). Information in the successional models synthesizes observed fire response and speculation based on dominant tree characteristics.

Fire groups provide generalized descriptions of fire behavior and plant response. Variation in fire behavior and successional patterns often depends on small local differences in fuel, moisture, topography, insolation, and tree seed availability. As a result, all stands in a habitat type may not fall into the same fire

group. The individual land manager's assessment of site conditions is the final determinant in identifying the appropriate multiple-pathway model.

All Montana fire groups currently defined are listed below. Groups One and Three do not occur in western Montana. They are included to clarify the Fire Group numbering system.

Fire Group Zero: A heterogeneous collection of special habitats. In western Montana forests these sites exist as scree, forested rock, wet meadow, mountain grassland, aspen grove, and alder glade.

Fire Group One: Dry limber pine habitat types. These exist almost exclusively east of the Continental Divide in Montana.

Fire Group Two: Warm, dry ponderosa pine habitat types. This group consists of both open ponderosa pine stands with a predominantly grass undergrowth and dense mixed-age stands of ponderosa pine. These sites may exist as fire-maintained grasslands and do not support Douglas-fir except as "accidental" individuals.

Fire Group Three: Warm, moist ponderosa pine habitat types. These sites occur exclusively east of the Continental Divide in Montana; they are often occupied by stagnant, overgrown thickets of ponderosa pine saplings.

Fire Group Four: Warm, dry Douglas-fir habitat types. These sites support fire-maintained ponderosa pine stands under a natural fire regime. Where fire is suppressed, Douglas-fir regenerates beneath the pine and eventually dominates the overstory.

Fire Group Five: Cool, dry Douglas-fir habitat types. Douglas-fir is often the only conifer present on these sites. In the absence of fire, a dense Douglas-fir sapling understory may develop.

Fire Group Six: Moist, Douglas-fir habitat types. Douglas-fir often dominates all stages of succession on these sites, even when subjected to periodic fire.

Fire Group Seven: Cool habitat types usually dominated by lodgepole pine. This group includes stands where fire maintains lodgepole pine as the major seral species as well as those stands in which lodgepole is a climax dominant.

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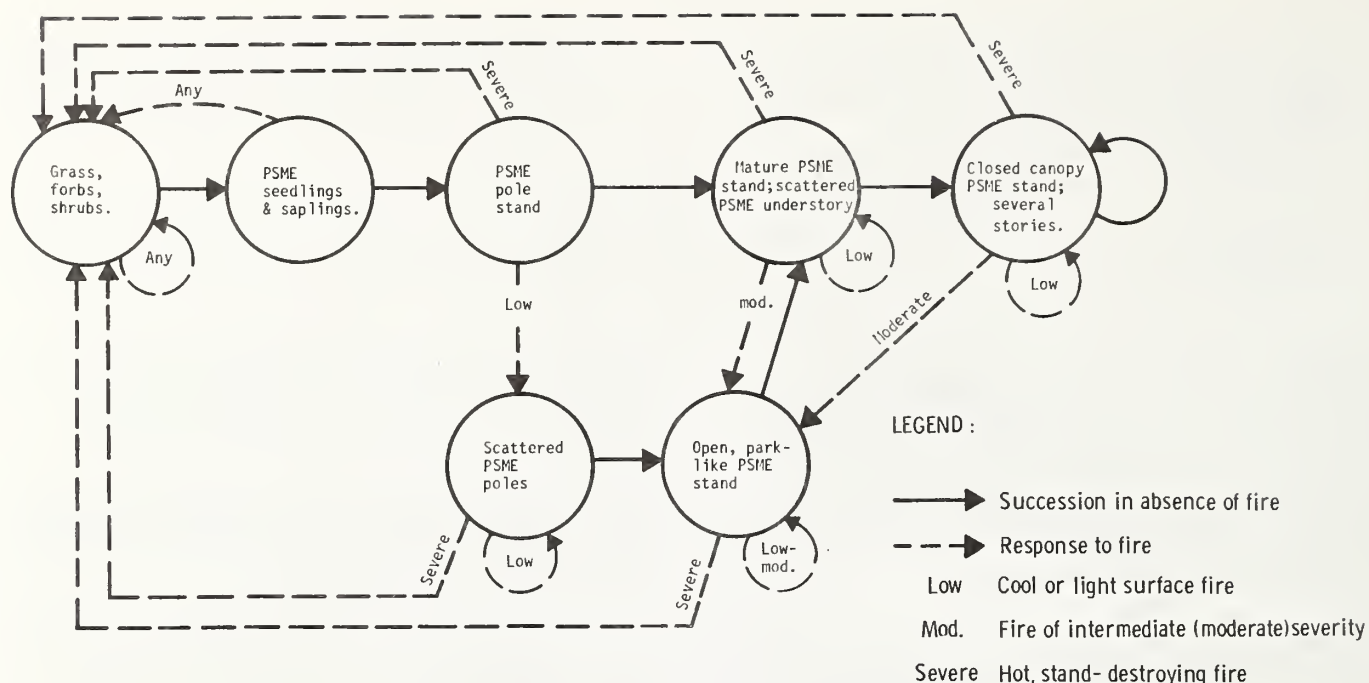


Figure 1--Hypothetical successional pathways for Fire Group 5: cool, dry Douglas-fir habitat types.

Fire Group Eight: Dry, lower subalpine habitat types. This is a collection of habitat types in the spruce and subalpine fir series that usually supports mixed stands of Douglas-fir and lodgepole pine.

Fire Group Nine: Moist, lower subalpine habitat types. Fires are infrequent but severe in these types, and the effects of fire are long lasting. Spruce is usually a major component of seral stands.

Fire Group Ten: Cold, moist upper subalpine and timberline habitat types. These types occur in high-elevation habitats where fires are infrequent. Fires are often small in areal extent because of sparse fuels. Severe fires have long-term effects. Subalpine fir, spruce, white-bark pine, and subalpine larch are the dominant conifers.

Fire Group Eleven: Moist grand fir, western redcedar, and western hemlock habitat types. These habitat types are found on moist sites where fires are infrequent but often severe. In Montana, they occur exclusively west of the Continental Divide.

Once a land manager has linked a habitat or vegetation type to a fire group, its associated multiple-pathway model can be used to provide a basis for making broadscale predictions of the effects of fires of varying severities occurring at different stages of stand development. Managers can use these predictions to estimate potential plant response to fire, or to decipher some of the factors responsible for creating the current landscape.

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STRATIFIED LANDSAT CLASSIFICATION OF NORTH-CENTRAL IDAHO
AND ADJACENT MONTANA

Bart R. Butterfield, Dan L. Davis, and James W. Unsworth

ABSTRACT: In 1985 we began a stratified Landsat classification to classify and map vegetation on 3.5 million acres of land in north-central Idaho and adjacent Montana and provide a habitat data base to wildlife managers and researchers. Our objective is to classify and map vegetation in sufficient detail to serve as a data base for elk and grizzly bear habitat research. However, we realize that we are creating a highly detailed and generic classification that has many potential applications, wildlife being just one. The classification involves five steps: (1) topographic classification, (2) Landsat spectral classification, (3) collection of reference, or ground-truth, data, (4) stratification, and (5) incorporation of additional data layers. Defense Mapping Agency digital elevation data were used to create three topographic data planes: elevation, aspect, and slope. Landsat 5 MSS data were classified into 150 spectral classes using a guided clustering approach. Reference data have been collected for 1½ field seasons and, when completed, will be used to correlate the spectral classes with plant communities. We have been able to correlate some groups of spectral classes to general vegetation types with our existing reference data. The topographic and spectral data layers will be combined and used to split, or stratify, spectral classes that represent two or more vegetation types into distinct classes based on topographic modeling. Additional data planes can be used to stratify spectral classes based on features such as hydrology, snowchutes, geographic location, or any feature that can be mapped or modeled. Stratified Landsat classes that represent the same or similar plant communities will be pooled together to form working habitat classifications. Classes can be pooled in different combinations to produce different vegetation classifications for a wide variety of applications.

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INTRODUCTION

Classifying and mapping vegetation on large expanses of remote, inaccessible land presents special difficulties. On-the-ground methods are limited by cost, time, and accessibility. Remote sensing provides greater coverage of the study area, but traditional aerial photograph interpretation suffers from lack of detail and variability in observer interpretation. Analysis of Landsat spectral data for applications in agriculture has proven successful and recent applications to wildland vegetation appear promising (Butterfield and Key 1986; Craighead and others 1982). Technological improvements in Landsat spectral data and analysis provide further promise in applications to wildland settings.

Faced with a need to classify and map wildlife habitat on 3.5 million acres of land, Clearwater National Forest, Nez Perce National Forest, and Idaho Department of Fish and Game joined in a cooperative effort to create a stratified Landsat classification of north-central Idaho and adjacent Montana in 1985. The primary author was contracted as an independent consultant to conduct the work. The major objectives are to classify, map, and evaluate grizzly bear habitat in the Bitterroot Mountains, and to classify and map elk habitat in the Clearwater Mountains. However, the actual process has been directed toward producing a detailed, but generic, vegetation classification which can be adapted to many different applications.

The study area consists primarily of the Bitterroot Mountains on the Idaho/Montana border and the Clearwater Mountains in Idaho. The entire area extends from north of Kelly Creek to just south of the Salmon River and from midway between Kooskia and Syringa, Idaho, to the Bitterroot Valley (fig. 1). Much of the study area is undeveloped, including the Selway-Bitterroot Wilderness Area, Gospel Hump Wilderness Area, and Frank Church-River of No Return Wilderness Area. Several other roadless areas are included as well as intensively managed areas on both the Clearwater and Nez Perce National Forests and adjacent National Forests.

Coniferous forests dominate the vegetation. North of the Lochsa River, western redcedar (*Thuja plicata*) and grand fir (*Abies grandis*) habitat types are prevalent. South of the Lochsa and Selway Rivers, these wetter types

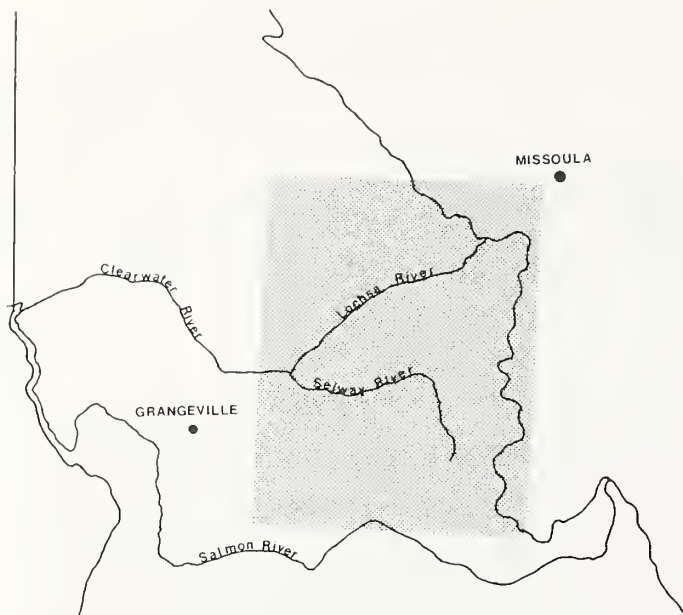


Figure 1--Location of the project area for the stratified Landsat classification of north-central Idaho and adjacent Montana.

give way to drier Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) habitat types. Subalpine fir (*Abies lasiocarpa*) habitat types occur above 5,000 to 6,000 feet elevation. Even-aged stands of lodgepole pine sometimes occur as fire regeneration, particularly south of the Selway River and in higher elevations to the north. Catastrophic fires in the early 1900's created large expanses of shrub fields north of the Selway and Lochsa Rivers, some of which even today lack conifer regeneration. Forb- and graminoid-dominated forest openings are patchy, but common. The forest cover is also broken by snow chutes in the Bitterroot Mountains. Although no true alpine vegetation occurs in the study area, an upper tree line exists in the Bitterroot Mountains due to the lack of soil and exposure of rock and its interaction with climate at higher elevations.

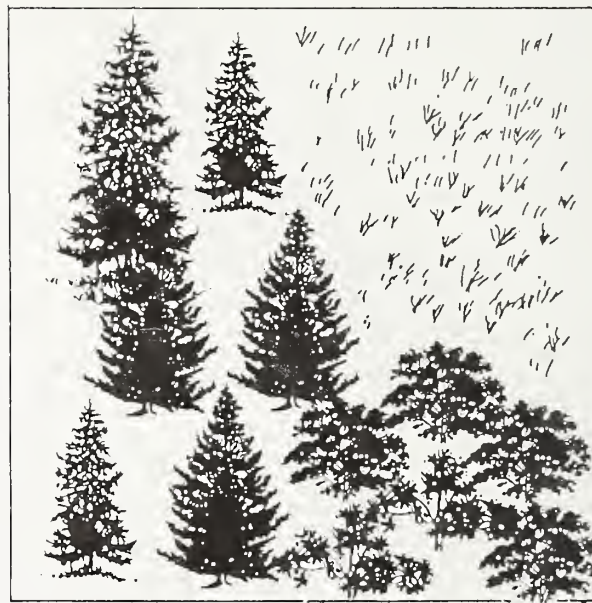
WHAT IS LANDSAT?

To fully understand the process and product, one must first understand Landsat and the concept of a digital image. Landsats are a series of satellites that circle the earth in circumpolar orbits. The satellites have several sensors on board that continuously measure and record the electromagnetic energy reflecting from the earth's surface. One of the sensors, the multispectral scanner (MSS) measures and records the earth's reflectance in four wavelength bands: green (0.5-0.6 μm), red (0.6-0.7 μm), infrared 1 (0.7-0.8 μm), and infrared 2 (0.8-1.1 μm).

The data are in the form of a digital image which can be envisioned as a huge grid over the earth's surface (fig. 2). For MSS data, the

cell dimensions are sized to 50 by 50 m. Each cell of the grid contains numeric values representing the reflectance value from the earth in each of the wavelength bands. Any attribute of the earth's surface that can be represented by a number can be in the form of a digital image. In addition to the spectral data, we have elevation, aspect, and slope images in the stratified Landsat classification.

EARTH SURFACE



DIGITAL IMAGE

8	15	13	13	30	41	55	48	50	51
10	16	14	14	35	38	50	45	48	52
9	10	12	10	28	40	52	50	51	48
10	13	14	11	25	42	55	53	54	51
11	10	12	8	15	50	61	63	60	58
11	13	14	13	25	63	72	74	78	81
13	11	10	11	28	62	80	84	82	84
10	12	8	12	30	58	86	90	89	90
12	14	15	13	15	78	85	88	86	89
11	12	10	9	18	72	87	90	91	89

Figure 2--Depiction of a small section of the earth's surface and a corresponding digital image of the raw spectral data.

PROCEDURES AND PROGRESS

Producing the stratified Landsat classification image from the raw spectral data involves five major steps (fig. 3). (1) Using Defense Mapping Agency digital elevation data we created three topographic images: elevation in 40-foot increments, aspect in 5-degree increments, and slope in 1-degree increments. (2) We classified the raw Landsat spectral data into 150 spectral classes using a guided clustering approach (Hart and Wherry 1984). This approach allowed us some subjective control over the selection of clusters while still accounting for all the spectral and vegetative diversity in the study area. (3) Each spectral class must be directly correlated to vegetation on the ground. We are currently at this stage. We locate ground plots for each spectral class on a variety of elevations, aspects, and slopes. Vegetation is sampled using the Ecodata Method of the Forest Service, Northern Region. (4) Correlation of spectral classes to vegetation may indicate that some spectral classes represent more than one type of vegetation. For example, a meadow and a subalpine park may be classified as the same spectral class, because both are dominated by herbaceous and graminoid vegetation and have similar reflectance characteristics. They can be separated, or stratified, by combining the spectral and topographic classified images and modeling the topography of the two different types of vegetation (meadows have flat or low slopes, sidehill parks have steep slopes). (5) Additional data layers may be used to model certain vegetation types. For example, surface hydrology corridors can be used to model riparian vegetation and snow chutes may be modeled by geographic area and topography. Other data themes such as roads and trails may be useful for later analyses. The final product will contain many data layers.

The end product will be a highly detailed, yet generic, vegetation classification. We predict we will have over 200 stratified Landsat classes when we are finished. Of course, that is far

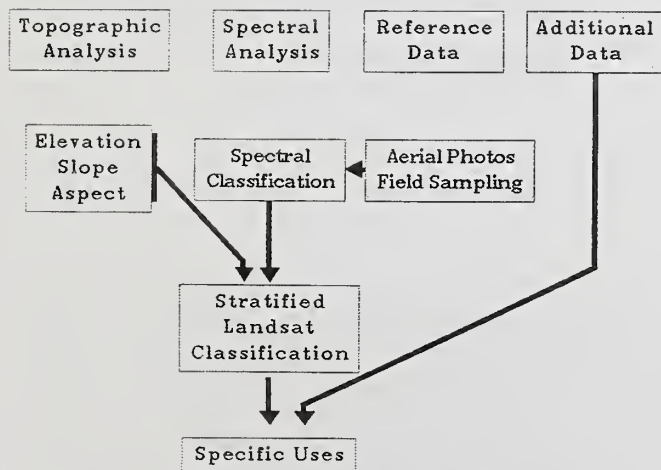


Figure 3--Flow chart of the stratified Landsat classification process.

too many classes for any practical application. Some stratified Landsat classes may be indistinguishable in terms of vegetation. The classification can be customized to fit most any application by pooling stratified Landsat classes to meet desired objectives.

APPLICATIONS

Grizzly Bear Habitat

The grizzly bear was classified as a threatened species in the conterminous 48 states in 1975 (USDI 1975). The official Grizzly Bear Recovery Plan (USDI 1982) identified the Bitterroot Mountains as one of six ecosystems for recovery of viable populations of grizzly bears. Little was known of the area including the population status of grizzly bears, the habitat value of the area, and even its political boundaries. The area has since been outlined and named The Bitterroot Evaluation Area (BEA).

The Recovery Plan prescribed two steps to be taken in the Bitterroot Mountains to assess the area's recovery potential: (1) determine the bear's population status and (2) evaluate the habitat for grizzly bear recovery. The presence of grizzly bears in the BEA is questionable, but unconfirmed reports are common (Melquist 1985). Scaggs (1979) and Butterfield and Almack (1985) have conducted cursory surveys of grizzly bear habitat in the Selway-Bitterroot Wilderness Area. The present study is a comprehensive inventory and evaluation of the entire BEA using a stratified Landsat classification.

Butterfield and Key (1986) demonstrated that stratified Landsat classifications can be effectively applied to grizzly bear habitat mapping. Our stratified Landsat classes will be grouped into vegetation types that best describe grizzly bear habitat components. Additional data layers will be needed to model snow chutes, fire regeneration, riparian corridors, and other habitat components used by grizzly bears.

Grizzly bear habitat models being developed by the Forest Service, Northern Region, will be applied to the digital grizzly bear habitat classification to evaluate habitat in the BEA. The models will extrapolate from grizzly bear habitat-use and food-habits data collected in other ecosystems that have viable grizzly bear populations.

Elk Habitat Use

Idaho Department of Fish and Game personnel are collecting radio-location data on elk in the Clearwater and Lochsa River drainages as part of a study to examine habitat use by elk. Because the stratified Landsat classification is geo-referenced to the Universal Transverse Mercator grid system, the radio-locations or home range calculations can be directly input into the stratified Landsat classification digital image. A variety of analyses can then be performed by

computer to examine habitat use. Stratified Landsat classes will be combined in the same manner the grizzly bear habitat classes were, but in combinations to meet the elk research and management objectives.

Other Applications

The stratified Landsat classification will be a very detailed breakdown of vegetation. The 150 spectral classes will result in approximately 200 stratified classes. Each stratified class will be correlated to some combination of plant species composition and abundance. Other data being collected for correlation include fuel classes, successional status, habitat type, ground cover, and basal area. With this data and the ability to combine the stratified Landsat classes in any combination desired, classifications for a variety of applications are possible. For example, stratified Landsat classifications may be useful for fire behavior modeling, habitat type mapping, and forest planning. Other data can be added in the future for other unforeseen applications.

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INTEGRATED INVENTORY--BRIDGER-TETON NATIONAL FOREST

T. M. Collins, M. Blackwell, J. Nordin, and A. P. Youngblood

ABSTRACT: Resource inventories have been integrated for a portion of the Teton National Forest and recorded on the same photographic base. This approach provides different combinations of information for managers. Information in this form may increase efficiency and effectiveness of resource manipulations such as prescribed burning, reforestation, wildlife improvement projects, and timber harvest.

INTRODUCTION

Interpretations based solely on single-resource inventories often have limited ability to predict various responses to management actions, especially the response of vegetation. Vegetation is often dynamic, with management options varying depending upon successional stage and past disturbance. Any given site, however, may support only one particular plant community at climax. This potential community is the result of integration of all environmental factors affecting the vegetation, including parent material, soil development, climate, fauna, and time. Similar sites or units of land that potentially support the same climax vegetation (habitat types) are useful for relating successional trends and communities, productivities, and responses to surface manipulations. Soil resource surveys, in contrast, provide little interpretive potential for projecting successional trends, productivities of seral communities, or responses of vegetation to prescribed fire or timber harvesting. Conversely, soil surveys provide data useful for considering road building alternatives while habitat type classifications may be of limited benefit.

This paper addresses an integrated inventory approach implemented on the Bridger-Teton

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National Forest in western Wyoming. Objectives were (a) to test the potential application of integrating soil resource survey, habitat type, and geologic hazard mapping across a large unit of land; (b) to provide essential information needed by management, in a suitable format, with the appropriate specificity; (c) to provide interpretations for various resource manipulations and management goals; and (d) to increase the utility and effectiveness of the inventory data by presenting them in a way that allows a variety of data combinations.

INTEGRATED INVENTORY METHODS

In 1980, a progressive soil resource survey of the Teton National Forest (now administered as part of the Bridger-Teton National Forest) was formally initiated. This Order III soil survey delineated contrasting soils to a minimum size of 40 acres. Map units were composed primarily of complexes and associations with soils classified at the family level (USDA 1975). The soil resource inventory was correlated to meet all USDA standards. At the same time, geologic hazard mapping was conducted for the survey area. Areas of mass movement, including active and stable landslides and rockfall, were mapped following established USDA Forest Service, Intermountain Region, guidelines (DeGraff and others 1979). Geology hazard mapping was conducted on a variety of air photo scales, but was later transferred to the soil inventory photo base.

Mapping of habitat types began in 1979 using map scales similar to the soil photo base. Habitat type maps delineated units of land with associations of habitat types and stable community types. Where habitat type maps were not available, extrapolation from adjacent areas, site data from project work, and observations made during the soil mapping were used.

Pairs of orthoquad mylars, consisting of the respective soil map and habitat type delineations, were superimposed and the occurrence of soil and habitat type delineations with correspondence were noted. Where delineation boundaries were similar, the occurrence was recorded. Units with repeated correspondence across a geographic distribution (throughout a single quad or on several quads) were reviewed for common conceptual features such as slope, aspect, topography, elevation, exposed rock, and existing seral vegetation.

A listing of each soil map unit and its corresponding habitat type units summarized the map overlay correlation. Computer-assisted sorting identified soil map units and habitat type units with high correspondence, indicating repeated common delineations (Youngblood 1984). The conceptual basis for each pair was reviewed to isolate common features such as topographic position and

geographic distribution. Similar soil map units with similar habitat type units were combined to form habitat type groups. Where appropriate, the groups were disaggregated based on slope or moisture criteria that may further refine and influence management options (for example, Groups 2D and 5A in tables 1 and 2).

Table 1--Example of range management interpretation from an integrated inventory, Bridger-Teton National Forest

Soil map unit	Erosion hazard	Revegetation limitation	Range productivity	Habitat type group ¹	Stability rating
110 (0-5% slopes) Alluvial terraces				2D	STABLE
SOIL 1 (30%)	LOW	SEVERE: STONES	LOW		
SOIL 2 (30%)	LOW	SEVERE: STONES	MODERATE		
SOIL 3 (30%)	LOW	SEVERE: STONES DROUGHTY	LOW		
202 (10-30% slopes) Rolling mtn. slopes				5A	M-STABLE
SOIL 1 (65%)	MODERATE: ERODES EASILY	MODERATE: SLOPE	HIGH		
SOIL 2 (25%)	HIGH: SLOW INTAKE PERCS SLOWLY	MODERATE: CLAYEY	HIGH		
459 (30-60% slopes) Benchy sideslopes				4	UNSTABLE
SOIL 1 (30%)	HIGH: PERCS SLOWLY SLOPE	MODERATE/SEVERE: SLOPE/ SLOPES <40%	HIGH		
SOIL 2 (25%)	HIGH: SLOPE EXCESS FINES	SEVERE/VERY SEVERE: SLOPE/ SLOPES <40%	MODERATE		
SOIL 3 (25%)	HIGH: SLOPE	SEVERE/VERY SEVERE: DROUGHTY/ SLOPES <40%	LOW		
616 (10-30% slopes) Foothills and basins				7	M-STABLE
SOIL 1 (50%)	HIGH: SLOW INTAKE PERCS SLOWLY	SEVERE: TOO CLAYEY SLOW INTAKE	MODERATELY LOW		
SOIL 2 (25%)	HIGH SLOW INTAKE PERCS SLOWLY	SEVERE: TOO CLAYEY SLOW INTAKE	HIGH		
646 (10-40% slopes) Hummocky earthflows				5A	M-UNSTABLE
SOIL 1 (60%)	MODERATE/HIGH: PERCS SLOWLY SLOPES <30%	MODERATE/SEVERE: SLOPES SLOPES <25%	HIGH		
SOIL 2 (25%)	HIGH: ERODES EASILY PERCS SLOWLY	MODERATE/SEVERE: TOO CLAYEY SLOPES <25%	HIGH		

¹See table 2 for explanation.

Table 2--Soil map unit-habitat type correlations from integrated inventory, Bridger-Teton National Forest

Habitat type group	Soil map unit	Habitat types	Other significant vegetation
2D	101 and 110	ARAR/AGSP ARLO/AGSP ARTRV/STCO	<u>Agropyron dasystachyum</u> <u>Agropyron smithii</u> <u>Stipa occidentalis</u> <u>Poa sandbergii</u>
4	340, 342, 456, 459	ARTRV/SYOR-AGSP ARTRV/SYOR-FEID ARTRV/STCO WYAM c.t. AGUR-VIMU c.t. BASA-HEUN c.t.	<u>Chrysothamnus viscidiflorus</u> <u>Prunus virginiana</u> <u>Berberis repens</u> <u>Eriogonum umbellatum</u> <u>Leucopoa kingii</u> <u>Crepis acuminata</u>
5A	202, 376, 646	ARTRV/FEID-GETR ARCA/FEID ARLO/FEID WYAM c.t. BASA-HEUM c.t.	<u>Bromus anomalus</u> <u>Stipa occidentalis</u> <u>Artemisia tripartita</u>
7	616	ARLO/FEID ARCA/FEID WYAM c.t.	<u>Wyethia amplexicaulis</u> <u>Potentilla fruticosa</u>

The soil map units within a habitat type group may have some similar responses to management if habitat types that comprise the group have similar responses. Table 2 lists the habitat type groups with their soil map units, the representative associated habitat and community types, and significant associated vegetation. Narrative descriptions of each habitat group were included in the final inventory report (Nordin and Blackwell 1987).

In this survey, the soil map unit or the component of the map unit became the integrating factor. The habitat type was considered in soil map unit design, but was used primarily to characterize the soil map unit. Active geologic hazards were mapped independently by geomorphologists. Geologic hazard potentials, however, were considered in map unit design. Active geologic hazards were included on the final maps.

APPLICATIONS AND MANAGEMENT

Utilization of integrated inventory information in management decisions and project activities is key in the acceptance of the inventory. Formulation of the inventory through an interdisciplinary approach may lead to more widespread use. Two examples will illustrate typical application of the data by resource managers.

Blue grouse, a native upland bird common to the northern Rocky Mountains, resides year round by adjusting its habitat by season and activity.

Wildlife management goals often include objectives for improving habitat and increasing distribution across potentially suitable land areas. Generally, these areas contain within close proximity a food source, such as pine and spruce seeds produced in old-growth, open conifer stands, hiding cover during brooding periods, such as open mountain slopes dominated by sagebrush and tall forbs, and a water source. These characteristics occur in part on Soil Map Units 342 and 456, which occupy south-facing slopes. The soils are generally shallow to moderately deep. Slopes are generally steeper than 50 percent, with numerous rock outcrops. Table 2 lists the habitat types in Group 4 that are generally associated with these soil map units. Wildlife managers may quickly recognize specific sites meeting the species habitat requirements, and identify acreages and locations suitable for wildlife habitat improvement projects. Alternatives for treatment and management practices could be derived from a combination of vegetative structure information based on plant succession and potential response of soils based on productivity and hazards.

Livestock grazing represents a major dispersed use of National Forest System lands. Efforts to reduce grazing impact and increase available forage are key management concerns. Increasing available forage often involves reduction of sagebrush cover by prescribed burning. Variables contributing to success include site productivity, erosion hazard, existing species composition, and the potential natural community

(habitat type). Site productivity and erosion hazard may be a function of soil moisture holding capacity, depth to bedrock, texture, rock fragment content, aspect, slope, and position on slope; these features are used to develop soil map units. Site productivity, existing species composition, and the potential natural community type are often derived from habitat type classifications. In western Wyoming, several species of sagebrush are often found on the same site. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) is easily killed by fire, while silver sagebrush (*Artemisia cana*) resprouts vigorously following burning. Habitat types supporting mountain big sagebrush but not silver sagebrush on soils with high productivity and low erosion hazard are identified as suitable for treatment by prescribed fire.

Tables 1 and 2 are examples of the kind of interpretative data that appear in the final report. Soil map units in table 1 have stability ratings and are linked to habitat type groups. Detailed habitat type and plant species information are presented in table 2, and cross-linked to various soil map units. Cross-linking provides various combinations of information for the user. For example, some soils in Map Unit 202 have characteristics desirable for prescribed burning for range improvement, such as moderate erosion hazard and high range productivity. Table 2 indicates, however, that Habitat Type Group 5A, which occurs on Soil Map Unit 202, may support silver sagebrush. Thus, the habitat type indicates a potentially limiting factor even though soil characteristics suggest the appropriateness of using prescribed fire for range improvement. In contrast, Habitat Type Group 4 indicates the presence of mountain big sagebrush and a good opportunity for range improvement. Soils in Map Unit 459, however, are highly erosive and unstable.

Interpretations traditionally based on physical soil properties are enhanced by knowledge of plant succession, geologic hazards, and revegetation potentials. Stratification of habitat types by specific soil properties enables application in areas where drastic ground disturbances are anticipated. Not all integrated inventories will require the same components. Because the portion of the Teton National Forest surveyed for this inventory contained landscapes with a high rate of mass movement, geologic hazard was selected as a component. This component need not be considered for areas with low rates of mass movement.

Unit costs for this integrated inventory were higher than traditional soil inventories, but were substantially lower than the cost of conducting the inventories separately.

SUMMARY

Complex landscapes and resource values suggested the need for an integrated inventory approach to resource survey on a portion of the Teton National Forest in western Wyoming. Topography, landform, habitat type, and geologic hazards, in addition to traditional soil survey data, were considered essential for providing resource management interpretations. The soil resource inventory was the mapping core of the integrated inventory, providing a mechanism for storage and a method for relating other resource information to uniform, repeatable land delineations. The nationally standardized mapping procedures, correlation, and quality control of the National Cooperative Soil Survey ensured consistency and increased utility of all resource data. This approach allowed a variety of resource information to be collected at one time for the same land area and recorded on the same photographic base. Managers may use several combinations of information provided by the integrated inventory in making decisions and increasing efficiency and effectiveness of resource manipulations such as prescribed burning, reforestation, wildlife improvement projects, and timber harvest.

While no detailed economic studies have been completed, we believe there are substantial dollar and time savings by using the integrated approach rather than the traditional individual resource inventory approach. User satisfaction is high and peripheral resource information is enhanced. Future use of the integrated information will likely be compatible with a variety of geographic information systems.

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AN EXAMPLE OF BIOPHYSICAL HABITAT MAPPING IN BRITISH COLUMBIA

Dennis A. Demarchi and E.C. (Ted) Lea

ABSTRACT: Information collected on site, soil, vegetation and wildlife and mapped at a scale of 1:20 000 is used to define management options for improving the habitat of selected wildlife species in the Sheep Mountain wildlife area in south-eastern British Columbia. An example of one biophysical habitat unit is described and management options are provided.

INTRODUCTION

The Sheep Mountain wildlife area is located in the southern portion of the Rocky Mountain Trench; south of Elko, between Highway 93 and the Elk River. In 1962 the B.C. Fish and Game Department purchased 64.8 ha at the base of Sheep Mountain and in 1985, a consortium of conservation groups (Wildlife Habitat Canada, Nature Trust, Kootenay Wildlife Heritage Fund and the Habitat Conservation Fund) purchased 364.2 ha that was owned by Jack Cutts.

Objectives

The policies and objectives that will guide the management and protection activities on the Sheep Mountain wildlife area are based, in part, on ecological information provided by a Biophysical Habitat inventory. The objectives of the biophysical inventory were to provide: an ecological framework for assessing the habitats used by big game animals during critical seasons of the year (in this case winter) and habitats used by other wildlife species; and for planning habitat enhancement activities (Lea and others 1987).

Wildlife

The Sheep Mountain wildlife area provides important winter habitat for a variety of big game animals, most numerous are elk and white-tailed deer, but, historically mule deer were abundant in periods of early successional stages. Bighorn sheep and moose also inhabit this winter range but their numbers are small, as the amount of habitat that could support these species is

limited. Other animal species on the Sheep Mountain wildlife area that are of management concern are: badgers, red-tailed hawks, golden eagles, and Columbian ground-squirrels.

Terrain Soils

The landscape of the Sheep Mountain area was shaped by glacial activity which occurred from 17,000 to 11,000 years ago, although downcutting of rivers occurred since then (Ryder 1981). Much of the area consists of materials that were deposited beneath 1,500-m-thick ice, called glacial till; or materials formed or deposited by flowing water surrounding or in front of the glacier, which are called fluvioglacial materials (Lacelle 1987).

Vegetation

The area, as was most of the Trench from the Tobacco Plains and Newgate areas north to Dutch Creek, was burned by two large fires in July, 1931. The resulting habitats were largely shrub/grass dominated. Since that time conifer trees have become reestablished over much of Sheep Mountain and the Trench (Lea 1984).

At present the vegetation of the Sheep Mountain area is characterized as having a mosaic of closed forests, open forests, shrub/grasslands and abandoned fields. The closed forests are dominated by Douglas-fir and ponderosa pine with a pinegrass understory. Open forests have Douglas-fir and ponderosa pine with an understory of antelopebrush, bluebunch wheatgrass, Idaho fescue and Junegrass. Shrub/grassland communities are seral to forests and are composed of antelopebrush, bluebunch wheatgrass, Idaho fescue, kinnikinnick and Junegrass.

AN EXAMPLE OF A SPECIFIC HABITAT UNIT

Douglas-fir - Antelopebrush Fluvial Habitat

This habitat unit is characterized by: level to gently rolling, fluvial plains that extend to the edge of the terrace face above the Elk River (See table 1 and fig. 1). Management of this habitat unit should consist of maintaining the existing openings by prescribed burning in 15-20 year intervals, except Douglas-fir should be planted around the perimeter of the cultivated fields at the Cutt's ranchstead. Cover that surrounds the open habitat should be maintained to provide visual barriers, temporary shelter and protect travel corridors for elk and white-tailed deer (See table 2 and fig. 2).

Poster presented at the Symposium on Land Classifications Based on Vegetation, Applications for Resource Management, Moscow, ID, November 17-19, 1987.

Dennis A. Demarchi is Habitat Classification Specialist; E.C. (Ted) Lea is Plant Ecologist; both are with Wildlife Branch, British Columbia Ministry of Environment and Parks, Victoria, B.C. Canada.

Table 1--DAF Douglas-fir - antelopebrush fluvial habitat unit (see fig. 1)

Description: Level to gently-sloped areas of terraces or plains with a sand to silt textured veneer of fluvial or aeolian (windblown) materials over a gravelly subsoil. Widespread unit in study area; slow rate of succession particularly in early stages which are quite droughty; slow establishment of trees; understory vegetation is more related to canopy cover than age of stand; hot burns in summer or fall will kill most of the antelopebrush; may be more potential for rough fescue than noted, as it appears to be heavily used; bluebunch wheatgrass and fescues are susceptible to overgrazing.

Map Symbol	Vegetation			
	Successional Trends		Ungulate Forage	
	Dominants	Associates	Abundant (>20% cover)	Moderate (5-20% cover)
DAF1*	shrub-grassland of: antelopebrush bluebunch wheatgrass Idaho fescue kinnikinnick Junegrass	saskatoon rose spreading needlegrass rough fescue Kentucky bluegrass orange arnica wild bergamot	antelopebrush bluebunch wheatgrass Idaho fescue	saskatoon rose kinnikinnick needle grasses rough fescue Kentucky bluegrass Junegrass pasture sage Hood's phlox
DAF2 DAF4 DAF6	parkland to open forests of: Douglas-fir ponderosa pine antelopebrush bluebunch wheatgrass Idaho fescue	saskatoon choke cherry rough fescue Junegrass pinegrass	Douglas-fir antelopebrush Idaho fescue	saskatoon choke cherry rose rough fescue needle grasses kinnikinnick Hood's phlox
DAF3 DAF5 DAF7	closed forests of: Douglas-fir pine grass	ponderosa pine snowberry birch-leaved spirea Oregon-grape rough fescue heart-leaved arnica	Douglas-fir	snowberry Oregon-grape mallow ninebark rough fescue bluebunch wheatgrass

*Successional Stages

1. Recent disturbance.
2. Young (less than 40 years), moderate forest canopy (25 to 65% cover).
3. Young (less than 40 years), dense forest canopy (greater than 65% cover).
4. Mature (40-120 years), moderate forest canopy (25 to 65% cover).
5. Mature (40-120 years), dense forest canopy (greater than 65% cover).
6. Old growth (greater than 120 years), moderate forest canopy (25 to 65% cover).
7. Old growth (greater than 120 years), dense forest canopy (greater than 65% cover).

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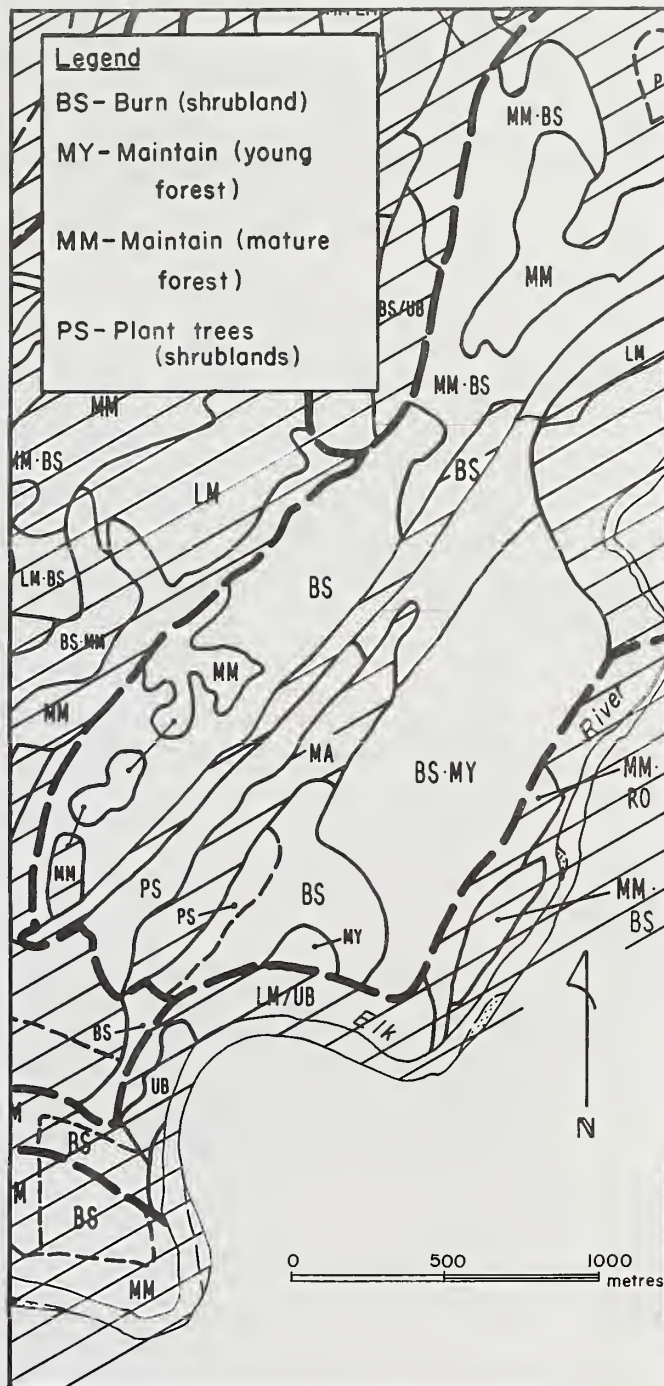
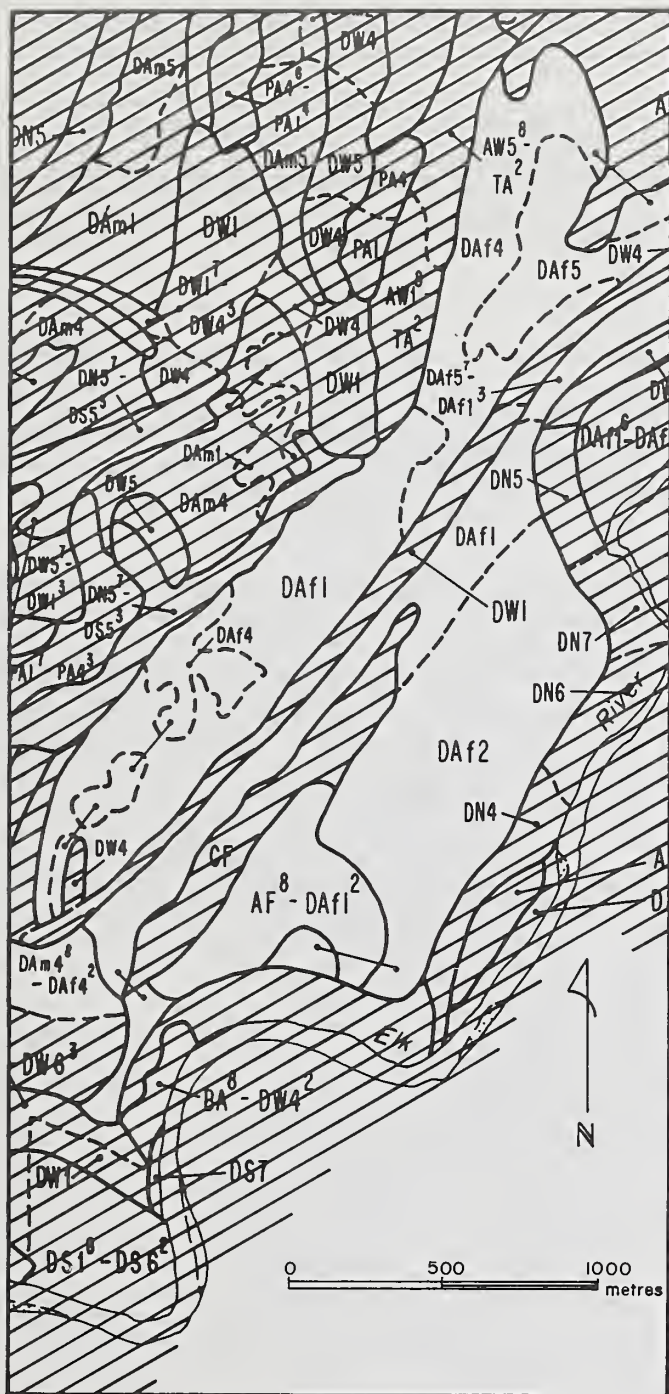


Table 2--Type of ungulate winter use and limitations, habitat manipulation considerations and treatment recommendations for the DAF Douglas-fir - antelopebrush fluvial Biophysical Habitat Units within Treatment Unit Three (see fig. 2)

Existing Successional Stages-Size and Number of Units	DAf 1 early succession (logged or heavily grazed) 103 ha/6	DAf 2 young trees (less than 40 years), moderate forest canopy (25-65% cover) 72 ha/2	DAf 4 mature trees (40-120 years), moderate forest canopy (25-65% cover) 61 ha/6	DAf 5 mature trees (40-120 years), dense forest canopy (greater than 65% cover) 38 ha/3
Present Winter Use suitability for: Elk	Forage high-mod.	Forage high	Forage mod.-high	Forage mod.
White-tailed Deer	Cover nil	Cover high	Cover high	Cover high
Mule Deer	high-mod.	high	mod.-high	high
Bighorn Sheep	mod.	mod.	mod.-high	low
	high	mod.	low	low
Limitations for present ungulate use	-little cover -heavily grazed -too flat for mule deer & bighorn sheep -only areas adjacent to escape terrain good for mule deer and bighorn sheep	-low snow interception -too flat for mule deer -adjacent escape too forested for bighorn sheep	-heavily grazed -too far from escape for bighorn sheep (except 2 units)	-canopy too dense for abundant forage -portion of large unit too far from escape terrain for bighorn sheep
Habitat Manipulation Considerations	-droughty, coarse soils -wind erosion may occur after disturbance -nutrient depletion may occur due to volatilization and leaching following burning -slow rate of succession -antelopebrush is killed by hot fires	-same as DAF 1 -canopy well spaced and clumped, excellent hiding cover	-same as DAF 1 -on the terrace these units often provide the first hiding cover from more open units -on the terrace face these units are only two of many forested units	-same as DAF 1 -these units are located between the most open units and the forested terrace face -these units are important as travel routes and hiding cover for all but bighorn sheep
Habitat Treatment Recommendations for: Elk	-prescribed burn in fifteen year cycles*; stagger the burning so not every unit is burned in the same year*; reduce cattle grazing*; in the largest units plant Douglas-fir in center to provide hiding cover*	-patch burn some of the unit in 15 year cycles to maintain opening* (some canopy can be eliminated but most is an asset); reduce cattle grazing*; one pass Christmas tree cutting*	-patch burn some of each unit in 15 year cycles to maintain openings and rejuvenate antelopebrush* (most of the canopy is an asset); reduce cattle grazing*; leave some canopy on all units*	-maintain canopy in all units*
White-tailed Deer	-as above	-as above	-as above	-as above
Mule Deer	-as above	-as above	-as above	-as above
Bighorn Sheep	-as above	-maintain largest openings nearest edge of terrace*	-manipulation of forest along terrace edge is in conflict with elk and white-tailed deer management	-management not applicable except for northern-most unit, between terrace edge and AF unit; excellent forage for bighorn sheep if completely cleared (management is in conflict with elk and white-tailed deer management)

*Recommended priority management activity for the specified successional stage.

BIOPHYSICAL HABITAT CLASSIFICATION IN BRITISH COLUMBIA:
AN INTERDISCIPLINARY APPROACH TO ECOSYSTEM EVALUATION

Dennis A. Demarchi and E.C. (Ted) Lea

ABSTRACT: The British Columbia Ministry of Environment and Parks has developed and implemented a multi-disciplinary, multi-scale habitat classification for wildlife and habitat planning and management purposes.

INTRODUCTION

Ecological classification and mapping done by the Wildlife Branch of the British Columbia Ministry of Environment and Parks is oriented toward identifying habitat for selected animal species, such as ungulates and bears. The emphasis on other animals is developing as requests for this information increase. The two main goals of biophysical mapping are (1) to provide a framework to assess the suitability and capability of the land surface for supporting wild animals (Demarchi and others 1983; Fuhr 1987) and (2) to provide a framework for improving animal habitat. The biophysical classification describes and maps land areas that have relatively homogeneous climatic, physical (including soil) and vegetative characteristics of importance to animals.

The hierarchy used for biophysical mapping includes Ecoregions, Biogeoclimatic Units (zonation) and Biophysical Habitat Units (table 1). Ecoregions are broad ecological units for the province, based on climatic processes, physiography, and broad animal and plant distribution (Demarchi 1987). Biogeoclimatic Units, as mapped by the British Columbia Ministry of Forests and Lands, provide a climatic framework for mapping within each Ecoregion, as well as a framework for mapping plant community distribution (Pojar and others 1986). In mapping, we usually use Biogeoclimatic Subzones. Biophysical Habitat Units, the lowest level of our mapping hierarchy, are relatively homogeneous units with respect to soils, surficial material, bedrock geology,

climate, topography, successional trends of vegetation and potential animal use (Demarchi and others 1988) (fig. 1). These units are divided into successional stages for mapping. Predictability of vegetation parameters is important to determine what areas can be improved for forage and cover for animals. We describe the vegetation, and potential forage and cover characteristics for animals, for all successional stages. Most of our interpretations for animals are done from these units. Our maps are presented at various scales, with 1:50,000 and 1:20,000 scales being most common.

In our classification and mapping, there is a strong emphasis on physical attributes, and successional as well as climax vegetation, as potential animal habitat use is strongly reflected by these features.

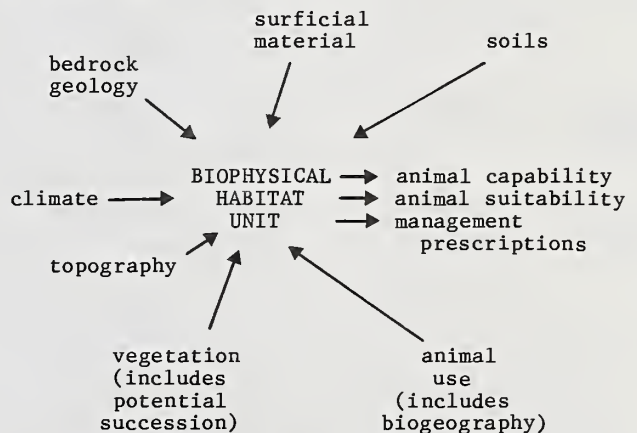


Figure 1--Parameters used to define Biophysical Habitat Units.

Field crews usually consist of a pedologist, who interprets bedrock geology, surficial materials and soils; a vegetation ecologist who interprets climatic parameters, succession and stand characteristics; a biologist who interprets current animal use and potential occurrence. All are responsible for developing habitat management interpretations. Our greatest successes began when scientists from all three disciplines were present during field trips, agreed to the location of each plot and then simultaneously sampled the site. Interpretations and unit delineation were also best served when the same air photos were used.

Poster presented at the Symposium on Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

Dennis A. Demarchi is Habitat Classification Specialist; E.C. (Ted) Lea is Plant Ecologist; both are with Wildlife Branch, British Columbia Ministry of Environment and Parks, Victoria, B.C., Canada.

Table 1--Physical and biological parameters that are considered when defining habitat units at various levels in the British Columbia, Ministry of Environment and Parks' Biophysical Habitat Classification

CLASSIFICATION LEVEL	SURVEY LEVELS & COMMON MAPPING SCALES	CLIMATE	PHYSICAL AND TERRAIN	BIOLOGICAL UNITS AT VARIOUS SCALES	PARAMETERS USED TO DETERMINE HABITAT	WILDLIFE
ECODOMAIN	Global 1:25 000 000	Broad Climatic similarity	-	-	Broad physiognomic groups (formation-type)	Faunal regions
ECODIVISION	Continental 1:12 000 000	Climate types	Continental Physiography	-	Similar physiognomic groups (formation)	Life zones
ECOPROVINCE	Sub-Continental 1:5 000 000	Macro-climatic processes	Physiographic systems	Soil Orders	Assemblages of vegetation regions and/or zones	Potential wildlife population ranges
ECOREGION	Provincial 1:2 000 000	Macro-climatic processes	Regional physiography	Soil Orders	Vegetation regions (assemblages of vegetation zones)	Wildlife biogeography (historical and potential distribution of populations)
ECOSECTION	Sub-Provincial 1:500 000	Macro-climatic process sub-regions	Regional physiography: regional bedrock	Soil great groups	Vegetation zones	Faunal communities
BIOGEO-CLIMATIC UNITS (ZONES)	Regional 1:250 000	Climatic regimes; macro-climatic parameters	Subdivision of regional physiography to represent groups of local landforms	Soil great groups	Climatic Climax communities	Faunal communities with belts of seasonal habitat use by migratory species
BIO-PHYSICAL HABITAT UNITS	Sub-Regional 1:50 000	Detailed level meso-climatic parameters	Local landforms; topography (slope aspect) parent materials	Soil Sub-groups, few classes (texture, depth, chemistry)	Plant communities (potential successional stages, including climax)	Units of potential seasonal use by migratory species (usually ungulates or grizzly bears)
BIO-PHYSICAL HABITAT UNITS	Watershed 1:20 000	Broad level micro-climatic parameters	Specific landforms and materials, many classes	Soil series, many classes	Plant communities (succession, physiognomy)	Wildlife biology and the influence of social behaviour on distribution and habitat use
BIO-PHYSICAL HABITAT UNITS	Special Area 1:5 000	Micro-climatic parameters	Materials	phases of soil series	Plant communities many classes	Specific animal use (fish, waterbirds and macroinvertebrates)

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THE SOIL-HABITAT TYPE RELATIONSHIP

Maynard A. Fosberg, Minoru Hironaka, and Kent E. Houston

BASIS

Soil and vegetation are functions of the soil-forming equation (Major 1951; Jenny 1958):

$$S, V = f(cl, p, r, o, t)$$

Soil (S) and vegetation (V) are functions of the independent factors climate (cl), parent material (p), relief or topography (r), biota (o), and time (t). The vegetation in this equation refers to the climax plant association. Since the habitat type is based upon the climax plant association, the two can be equated. However, this relationship is only true when the habitat type is supporting climax vegetation and the soil is classified at the series level.

FACTS AND CONCEPTS

- * A soil series is associated with only one habitat type. A habitat type, however, can be found on more than one soil series. This is due to the ability of plants to compensate for environmental differences.
- * The habitat type is correlated with the soil series and not the family level of soil taxonomy.
- * The habitat type correlates to some, but not all, soil characteristics used in soil taxonomy.
- * The habitat type is associated with the net effect of all the soil properties.

APPLICATIONS

- * Habitat types and soil types should be delineated in concurrent classification

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programs to achieve the maximum benefit of both systems.

- * Habitat types should be used to help delineate the soil series or phase.
- * Habitat types can be used to interpret soil moisture and temperature regimes within a local area.
- * Habitat types can be used to predict site or soil potential.

SOIL PROPERTIES THAT CORRELATE WITH HABITAT TYPES

Habitat types are primarily associated with the net effect of several soil properties. The most important of these include:

- * Soil moisture and temperature regimes
- * Depth to restricting layers (clay pans, duripans, or bedrock)
- * Type of parent material
- * Thickness and color of the surface horizon
- * Depth to lime
- * Degree of soil development
- * Texture
- * Clay accumulation
- * Mineralogy
- * Presence or absence of volcanic ash

Two examples of shrubland-associated soil series from southern Idaho illustrate the importance of these properties. These two soils are distributed on the landscape in a complex mosaic pattern. Knowledge of the effects of the soil characteristics allows the prediction of either habitat type or soil type.

Triangle Series

Artemisia arbuscula/Festuca idahoensis
habitat type

Fine-loamy over clayey, mixed, Duric
Cryoboroll

Soil Characteristics:

Well-developed clay restricting layer
within 12 inches of the surface
Thin, dark surface
Low water holding capacity
Poor root aeration

Caudle Series

Artemisia tridentata spp. vaseyana/Festuca idahoensis habitat type

Fine-loamy, mixed Argic Pachic Cryoboroll
Characteristics:

No restricting layer
Over-thickened, dark surface layer (high organic matter content)
High water holding capacity
Good root aeration
Relatively uniform texture throughout the soil profile

Two examples of soil series from northern Idaho forests illustrate the importance of these properties. These two soils represent different influences on vegetation from loess and volcanic ash parent materials.

DeMasters Series
Pinus ponderosa/Festuca idahoensis habitat type
Fine-loamy, mixed, frigid, Pachic Ultic Argixeroll
Characteristics:

Mixed, loess-influenced mineralogy
Xeric moisture regime
Over-thickened, dark surface layer (high organic matter)

Unnamed Soil Series

Thuja plicata/Gymnocarpium dryopteris habitat type

Medial over loamy, mixed, frigid, Typic Vitrandept
Characteristics:

Ash surface mineralogy
Udic moisture regime
Light-colored surface layer (low organic matter)

CONCLUSIONS

The soil and habitat type relationships are interrelated and complex. These relationships require that soil scientists and plant ecologists work together to optimize landscape delineation and predictions of management responses.

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COMPUTERIZED MAPPING OF UTAH'S DISTRIBUTION

OF MAJOR PLANT COMMUNITIES

Dan A. Foster and Robert H. Foster

ABSTRACT: The distribution of major plant communities in the state of Utah was computerized, then plotted in map form, using geographic information system (GIS) technology. The computerized plant community information can be used, whole or in part, to rapidly aid in land management decisions and planning in large-scale applications. Data sources, methodology, problems faced, and potential uses are discussed.

INTRODUCTION

One of the major problems of land management in Utah is an accurate assessment of the vegetative cover in the state. In 1985 the Division of State Lands and Forestry in connection with the Automated Geographic Reference (AGR) office began a project to address this problem. The objective of the project was to develop a computerized coverage of the major plant communities in the state on a scale that would allow broad-based land management decisions. Also desired was the ability to increase the map detail by continuous database revision.

METHODS

Computerized mapping of Utah's major plant communities was done in two stages. The first stage was the input of initial mapped information from the dissertation map compiled by Foster (1968). The dissertation map was developed using a combination of aerial photographs and field surveys (Foster 1968). The initial map information was digitized at a scale of 1:500,000 using the ARC/INFO software run on the AGR Prime 550 computer. ARC/INFO is a GIS software package allowing computer graphics, image processing, and computational geometry under ARC, and an extensive data base management system with INFO (Environmental Systems Research Institute 1985; Marble 1984).

Poster presented at the Symposium on Land Classifications Based on Vegetation: Applications for Resource Management, Moscow, ID, November 17-19, 1987.

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The hierarchical letter-number codes of the dissertation map were used to delineate vegetation communities and species within communities and are as follows:

- A. Conifer-Aspen
 - 1. Utah Juniper
 - 2. Rocky Mountain Juniper
 - 3. Common Juniper
 - 4. Pinyon Pine
 - 5. Singleleaf Pinyon
 - 6. Aspen
 - 7. Douglas-fir
 - 8. White Fir
 - 9. Subalpine Fir
 - 10. Blue Spruce
 - 11. Engelmann Spruce
 - 12. Ponderosa Pine
 - 13. Limber Pine
 - 14. Lodgepole Pine
 - 15. Bristlecone Pine
- B. Mountain Brush
 - 1. Oak
 - 2. Maple
 - 3. Cliffrose
 - 4. Bitterbrush
 - 5. Mountain Mahogany
 - 6. Serviceberry
 - 7. Squawbush
 - 8. Choke Cherry
 - 9. Gooseberry
 - 10. Currant
 - 11. Snowberry
 - 12. Woodrose
 - 13. Oregon Grape
 - 14. Ceanothus
 - 15. Arctostaphylos
 - 16. Honeysuckle
 - 17. Box Elder
- C. Herbs-Shrubs
 - 1. Sagebrush
 - 2. Greasewood
 - 3. Shadscale
 - 4. Mat-atrilex
 - 5. Castle Valley Clover
 - 6. Rabbitbrush
 - 7. Horsebrush
 - 8. Russian Thistle
 - 9. Pickleweed
 - 10. Halogeton
 - 11. Winterfat
 - 12. Mormon Tea
 - 13. Snakeweed
 - 14. Blackbrush
 - 15. Creosotebush

16. Bursage
17. Prickly Pear
18. Buffaloberry
19. Singleleaf Ash
20. Fremont Mahonia
21. Whitetop
- D. Grasses-Sedges
 1. Cheatgrass
 2. Ricegrass
 3. Dropseed
 4. Saltgrass
 5. Wheatgrass mix
 6. Galleta
 7. Needlegrass
 8. Foxtail
 9. Bluegrass
 10. Grama
 11. Brome
 12. Three Awn
 13. Trisetum
 14. Fescue
 15. Sedge
 16. Seeded
 17. Reedgrass
 18. Timothy
 19. Crested Wheat
 20. Yucca
- E. River Bottom
 1. Fremont Cottonwood
 2. Narrowleaf Cottonwood
 3. Willow
 4. Tamarisk
 5. Russian Olive
- F. Cultural Forms
 1. Cities
 2. Cultivated Land
- G. Physical Forms
 1. Water
 2. Alkali
 3. Sand
 4. Mud
 5. Wasteland
 6. Playa

This system allows for the delineation of dominant and codominant species by using upper case letters and using lower case letters for related species. This system is similar to, but more detailed than the numerical system used by Küchler (1975). The database management system of ARC/INFO allowed for easy input of the major communities, species within communities, and shade patterns for polygons representing each community. Conversion from this classification system to others is easily facilitated in the software. For example, the more rigid system used by Welsh and others (1987) could be implemented.

By inputting the original map, an automated "snapshot" of the state's vegetative cover was made available for roughly a 20-year comparison of vegetative trends.

The second stage of the project was field surveying to update the original map and input of the new data into the digital database. Extensive field reconnaissance was done to check the status of plant communities and record changes of major distribution throughout the state. ARC/INFO capabilities allowed rapid and accurate line and polygon

changes to computerized data of vegetation changes and correction of mapping errors.

The update coverage information on water bodies and rivers was obtained from overlaying the Bureau of Land Management's Areas of Responsibility and Land Status map at 1:500,000 scale (Bureau of Land Management 1975). City information was obtained from the Utah Department of Transportation's General Highway Map series at 1:125,000 scale (Utah Department of Transportation 1975).

RESULTS

Fifty major plant communities were mapped. Eight additional communities were included as cultural and physical forms. Seventy-eight major plant species were included in the coverage. Over 1,200 polygons were created depicting the plant community coverage for the 1968 data and over 1,300 for the update coverage of 1987.

Using a Calcomp 1077 plotter, both the 1968 and 1987 coverages were produced in map form at a scale of 1:750,000. These maps were plotted in 10 colors with 58 shade patterns and included a 1° x 1° tile for latitude-longitude, distance scales, map references, and a full key.

DISCUSSION

Two problems were encountered during the development of the computerized plant community coverage. The first was in the variance of the original base map for automated cartography. Although the original plant coverage and the statewide base maps were at 1:500,000 scales, errors were encountered in the digitization process which showed the publication projections of the maps were actually different. This in effect displaced the registration points of the digitizing and necessitated the transformation of the automated plant coverage to fit the existing computerized state base map. Transformation of the digital data resulted in the "stretching" of polygon features to fit both the X and Y axis of the base map. Extensive cleaning was necessary to repair the effects of the transformation to ensure that polygon features resided in the proper areas, that is, river bottoms matched the river drainages, and so on.

The second problem encountered was the lack of current digital or hard-copy-mapped information available to us in building an up-to-date coverage. The coverages used to build the water bodies and city areas were not as recent as desired, but were used out of necessity.

As mentioned before, a 20-year vegetation trend comparison was made for the state which showed that major increases have been made by some communities of grasses, specifically in the cheatgrass encroachment of shrubland. Other changes can also be seen.

Automated capabilities enable the plant coverage to be used for such studies as range trend, impact analysis, and mitigation procedures. The limiting factors to usage are the availability of associated study coverages and the desired scale of output. With continual update the scale of output can be decreased to reflect greater map accuracy.

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PLANT COMMUNITY CLASSIFICATION OF EL MALPAIS, NEW MEXICO

Richard E. Francis and Tod B. Williams

ABSTRACT: Twenty-seven sites on El Malpais were quantified and classified into 19 existing plant communities representing 3 formations and 7 subformations. The plant communities form an ecological data base for management.

INTRODUCTION

El Malpais (lava flow badlands) is located south of Grants in west-central New Mexico. The study area is approximately 34,000 ha in size with elevations ranging from 2154 to 2360 m. The mean annual precipitation is between 227 and 357 mm. Four lava flows are bordered on the east by sandstone bluffs and on the west by numerous volcanic cones. The oldest flow was about 3,000 years ago, and the newest is about 800 years old (USDI BLM 1982; Armstrong 1983). The soils are exposed lava flows (basalt) surrounded by shallow to moderately deep soils on several landforms.

The objective of our study was to quantify and classify the existing plant communities directly on, or influenced by, the lava flows. The intent of this paper is to provide an approach to plant community classification using El Malpais as an example.

METHODS

Twenty-seven homogeneous sample sites were selected on and around the lava flows. The sites were selected as being representative of the area and three permanent transects were established at each site. The sites were sampled using 100 5x10-cm microplots (Morris, 1973) per transect for foliar cover, and 10 0.5-m² circular plots per transect for density and frequency, collectively known as Community Structure Analysis (CSA) (Pase 1981). The CSA estimates included bare soil, litter, and rock. Importance values (IV) for plant species were calculated from relative foliar cover, relative density, and relative

frequency; maximum IV=3.0. IV's ≥ 0.1 were used to calculate resemblance matrices consisting of dissimilarity coefficients derived from Euclidean distance coefficients (Sneath and Sokal 1973; Romesburg 1984).

A dendrogram was produced using Ward's (1963) clustering method from Program CLUSTAN (Wishart 1981) based on the minimum variance between two sites (Romesburg 1984). The cluster routine followed a hierarchical-agglomerative-polythetic approach (Goodall 1978; Romesburg 1984). The resultant dendrogram (fig. 1) was interpreted for realistic clusters using individual site summaries (table 1), successive approximation (Poore 1962), and site photos. Herbaceous production was estimated by double sampling 10 0.89-m² plots per transect; estimates were made by species and total weight.

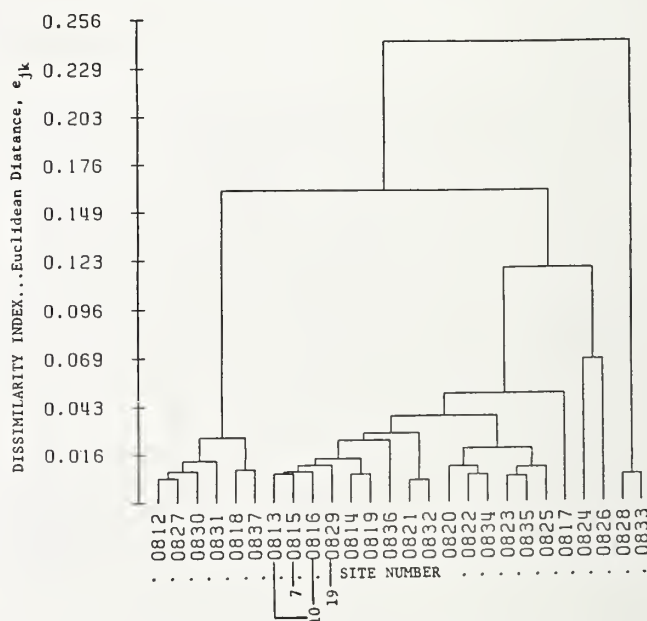


Figure 1--Dendrogram of 27 El Malpais sites using species IV ≥ 0.1 . Connected sites represent 3 of the 19 plant communities: P.C. 7, 10, and 19.

RESULTS

Nineteen existing plant communities (table 2 and 3) were described following interpretation of dendrogram clusters, site summaries, and supplemental information. The 19 communities

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Table 1--Partial site summary of species variables from 4 El Malpais sites following the horizontal dendrogram x-axis. Underlined species were used to form and name the plant community (P.C.)

P.C. no.	Site no.	Species ¹	Foliar cover (%)	Density (no.)	Frequency (%)	IV	Herbaceous production (kg/ha)
10	813	Bogr	7.2	22.8	97	0.623	140
		Annu	3.8	23.4	87	.514	10
		Lich	3.9	10.8	63	.333	
		Sihy	3.3	5.2	80	.267	15
		Semu	1.4	6.9	50	.193	56
		Gusa	1.8	2.5	67	.172	127
		Hyri	1.9	0.8	37	.116	
		Teca	1.5	0.4	33	.096	
		Other	8.2	32.6		.686	31
			33.0	82.0		3.000	379
7	815	Bogr	4.0	21.5	93	.648	94
		Annu	1.0	9.6	73	.315	6
		Lich	2.7	6.8	63	.306	
		Gusa	3.1	4.1	67	.279	165
		Pied	6.8	0.1	7	.235	
		Arca	2.3	4.1	37	.203	
		Jumo	4.3	0.1	3	.146	
		Sihy	0.7	2.2	33	.113	13
		Hyri	1.2	0.6	37	.108	
		Other	3.9	9.9		.647	118
			30.0	59.0		3.000	396
	816	Bogr	4.1	34.7	93	.638	59
		Gusa	8.1	11.5	97	.517	522
		Lich	5.5	18.5	90	.501	
		Annu	1.8	13.2	93	.328	29
		Leer	1.0	3.1	60	.146	
		Chpa	2.6	0.2	20	.115	
		ERIG	0.3	1.9	60	.111	
		Spco	0.5	1.2	57	.107	
		Teca	1.1	0.4	30	.078	
		Other	6.0	6.3		.459	590
			31.0	91.0		3.000	1200
19	829	Bogr	7.0	46.1	83	.882	76
		Lich	4.9	15.3	60	.434	
		Arfr	5.8	2.9	60	.330	56
		Gusa	3.5	3.3	87	.301	290
		ERIG	1.4	4.5	53	.185	
		Annu	0.5	1.9	63	.144	
		Other	5.9	17.0		.724	193
			29.0	91.0		3.000	615

¹ Plant communities and species binomial symbols are listed in tables 2 and 3, respectively.

represented 3 formations (dominant lifeform) and 7 subformations (dominant genus).

Site summaries were an integral part of interpreting and adjusting the dendrogram clusters. For example, at dissimilarity index 0.016, sites number 813, 815, 816, and 829 were directly linked (fig. 1); the first three sites were dominated by Bogr (IV>0.6), Gusa (IV>0.1), and Lichen (IV>0.3) (table 1). However, that dominance was considered modified by the presence of other lifeform synusia: sites 813 and 816 with Teca (IV~0.1), a shrub, and site 815 with the presence of two trees, Pied (IV>0.2) and Jumo (IV>0.1). Therefore, the three sites were recombined to form two distinct communities based on lifeform synusia and associated variables (P.C. 7 and 10). Site 829 was considered distinct by the dominance of Arfr (IV>0.3) and Gusa (IV>0.3) in association with Bogr (IV>0.8) and named P.C. 19 (table 1).

The range of site variables were 1) foliar cover 30-60%, 2) bare soil 0-87%, 3) litter 10-51%, 4) rock 0-57%, and 5) herbaceous production 60-1,200 kg/ha.

Table 2--Existing plant communities of El Malpais, New Mexico. Species dominance was based on an importance value ≥ 0.1 calculated from relative foliar cover, relative density, and relative frequency

FORMATION	SUBFORMATION	COMMUNITY ²
TREELAND	<u>Pinus</u>	1. Pipo/Mumo-Bogr
		2. Pipo/Mumo-Bltr
		3. Pipo/Mumo-Pofe
		4. Pipo/Fspa/Bogr
		5. Pied/Quun/Mumo
		6. Pied/Gusa/Bogr/Lich
		7. Pied-Jumo/Bogr/Lich
	<u>Juniperus</u>	8. Jumo/Bogr-Spcr
		9. Jumo/Gusa/Bogr
SHRUBLAND	<u>Tetradymia</u>	10. Teca-Gusa/Bogr/Lich
		11. Teca-Gusa/Hyfi/Bogr
	<u>Artemisia</u>	12. Arfi/Bogr
	<u>Chrysothamnus</u>	13. Chnab/Bogr
		14. Chnab-Gusa/Spcr
	<u>Fallugia</u>	15. Fapa-Chvi/Ansc
GRASSLAND	<u>Bouteloua</u>	16. Bogr/Spco-Agsm
		17. Gusa/Bogr/Lich
		18. Gusa-Chpa/Bogr
		19. Arfr-Gusa/Bogr

² See Table 3 for species binomials.

Table 3--Plant species symbols and binomials used in naming El Malpais plant communities. Taxonomy follows Nickerson and others 1976; Martin and Hutchins 1980

Species symbol	Species binomial
Agsm	<u>Agropyron smithii</u>
Ansc	<u>Andropogon scoparius</u>
Annu	Annuals
Arca	<u>Artemisia carrutherii</u>
Arfi	<u>Artemesia filifolia</u>
Arfr	<u>Artemesia frigida</u>
Bltr	<u>Blepharoneuron tricholepis</u>
Bogr	<u>Bouteloua gracilis</u>
Chnab	<u>Chrysothamnus nauseosus</u>
	ssp. <u>bigelovii</u>
Chpa	<u>Chrysothamnus parryi</u>
Chvi	<u>Chrysopsis villosa</u>
ERIG	<u>Erigeron</u> spp.
Fapa	<u>Fallugia paradoxa</u>
Gusa	<u>Gutierrezia sarothrae</u>
Hyfi	<u>Hymenopappus filifolius</u>
Hyri	<u>Hymenoxys richardsonii</u>
Jumo	<u>Juniperus monosperma</u>
Lich	Lichen
Mumo	<u>Muhlenbergia montana</u>
Pied	<u>Pinus edulis</u>
Pipo	<u>Pinus ponderosa</u>
Pofe	<u>Poa fendleriana</u>
Semu	<u>Senecio multicapitatus</u>
Sihy	<u>Sitanion hystrix</u>
Spco	<u>Sphaeralcea coccinea</u>
Spcr	<u>Sporobolus cryptandrus</u>
Teca	<u>Tetradymia canescens</u>
Quun	<u>Quercus undulata</u>

CONCLUSIONS

Results of this study form an ecological data base of quantitative community descriptions (Francis 1986) to interpret and monitor successional stage and management prescriptions, and to form a monitoring base for ecosystem dynamics (trend). The data also provide a quantitative base to establish the relationship of plant communities to soils and landform. The study is applicable to the management and subsequent evaluation of similar environments.

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SOIL FUNGI: AN ADDITIONAL PARAMETER
FOR PHYTO-EDAPHIC COMMUNITY CLASSIFICATION

P. R. Fresquez, G. L. Dennis, and R. E. Francis

ABSTRACT: The utility of soil fungi in phyto-edaphic community classification was tested by determining the relationships between the soil fungal communities and the physiochemical properties of soils associated with plant communities in the semiarid Southwestern United States. Populations of fungi were significantly higher in soils from treeland plant communities as compared to shrub or to grassland plant communities. In contrast, the diversity of fungal groups was higher in the shrub and grassland plant communities than in the treeland plant communities. The community composition of fungal groups differed considerably among the three major plant life-forms, indicating that the soils from each plant community had a distinct fungal community composition. Fungal parameters in association with the soils chemistry offer a useful means of describing ecosystem dynamics, in terms of identifying more productive soils, and/or soils that are physiochemically stressed.

INTRODUCTION

Traditionally, land classification has been based on the description of plant communities or the identification of plant communities associated with specific soils (i.e., phyto-edaphic classification) (Daubenmire 1970, Mueggler and Stewart 1980, Youngblood and Mueggler 1981, Tiedeman and others 1987). A more ecologically sound classification of phyto-edaphic communities should result from quantifying and describing the biotic component of the belowground ecosystem as well. Soil microbial populations respond more rapidly to changes or to fluctuations in the soil environment than do plants (Atlas and Bartha 1981). Determining soil microbial parameters in association with soil physical and chemical characteristics may help to describe ecosystem dynamics in terms of identifying more productive soils, or soils that are physiochemically stressed (Fresquez and others 1986).

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Soil fungal populations, diversity, and community composition are related to soil properties as influenced by vegetation (Tresner and others 1954, England and Rice 1957, Mallik and Rice 1966, Badurowa and Badura 1967, Wicklow and others 1974, Christensen 1981). Such site-specificity should make soil fungi a useful additional parameter to better describe and interpret phyto-edaphic communities. In this preliminary study, the utility of soil fungi in phyto-edaphic community classification was tested by determining the relationships between the soil fungal communities and the physiochemical properties of soils associated with plant communities in the semiarid Southwest.

MATERIALS AND METHODS

Forty-five plant communities have been quantified and classified in the Upper Rio Puerco Watershed of northwestern New Mexico (Francis 1986). Of the 45 communities, 11 were considered the most representative--2 treeland, 5 shrubland, and 4 grassland types:

Treeland plant communities

1. Pinus ponderosa/Carex filifolia - Bouteloua gracilis
2. Juniperus monosperma/Bouteloua gracilis

Shrubland plant communities

3. Artemisia tridentata - Gutierrezia sarothrae/Bouteloua gracilis - Agropyron smithii
4. Chrysothamnus parryi/Bouteloua gracilis - Agropyron smithii
5. Sarcobatus vermiculatus/Sitanion hystrix - Hilaria jamesii
6. Ceratoides lanata - Gutierrezia sarothrae/Hilaria jamesii
7. Atriplex canescens/Sporobolus airoides - Sitanion hystrix

Grassland plant communities

8. Gutierrezia sarothrae/Bouteloua gracilis - Hilaria jamesii
9. Gutierrezia sarothrae/Hilaria jamesii - Bouteloua gracilis
10. Sporobolus airoides - Bouteloua gracilis
11. Scleropogon brevifolius - Bouteloua gracilis

Each selected plant community contained a minimum of three 180-m permanent line transects from which soils were sampled in August 1986. Soil samples were analyzed for numerous physical and chemical properties as well as the numbers and types of soil fungi (Fresquez and others 1987).

Variations in the soil physical and chemical variables and in the populations of soil fungi from the three plant formations were analyzed using one-way analysis of variance. The Least Significant Difference (L.S.D.) test ($p \leq 0.05$) was used to compare soil parameters and fungal population means among the formations. Also, Pearson's correlation coefficients were used to compare fungal populations with soil chemical parameters among the formations. Three indexes were used to compare the distribution patterns of soil fungal groups among the plant formations: Shannon's index of species diversity and an associated evenness index (Greig-Smith 1983) and Sorenson's presence community coefficient (SPCC) (Mueller-Dombois and Ellenberg 1974).

RESULTS AND DISCUSSION

Soils associated with treeland plant communities had significantly higher fungal populations compared to soils associated with shrub or grassland plant communities (table 1). Increasing numbers of fungal propagules in the treeland communities were significantly correlated with decreasing soil pH and with increasing total N, P, and organic matter (Fresquez and others 1987). In contrast, the diversity and evenness of fungal groups were higher in soils from the shrub and grassland plant communities than in soils from the treeland plant communities. Lower populations of fungi and higher fungal diversities in the shrub and grassland plant communities were associated with a lower soil organic matter status compared to the more organic matter rich treeland plant communities.

The composition of fungal groups differed considerably among the soils from the three major plant formations, indicating that each had a distinct fungal community composition. Based on Sorensen's presence community coefficient, the similarity of fungal groups among the soils from

the three major plant growth forms was very low. Soil fungal communities associated with the treeland plant communities were more similar to the fungal communities associated with the grasslands (44%) than to those found in the shrublands (35%). The differences in the composition of fungal groups among the three major plant growth forms were not unexpected. Because of the differences in the amounts and types of plant materials produced by the different plant communities, the amount and type of fungi occupying a given site should change (Badurowa and Badura 1967). For example, the combined soil microfungi from both of the treeland plant communities could be readily distinguished from the shrub and grassland soil fungi. Treeland soils characteristically yield a greater diversity of *Penicillium* species, which usually constitute a relatively higher proportion of the total isolates (States 1978, Christensen 1981). Although *P. cyclopium* dominated the soils from both the tree and shrubland plant communities, the overall similarity in the composition of the fungal communities of these two plant formations was still very low (35%). In comparison to the soils from the tree and shrubland formations, the grassland plant communities were dominated or codominated by the genus *Fusarium*, which is characteristic of grassland plant communities (Christensen 1981).

The differences in populations, diversities, and the composition of fungal groups among the three major plant growth forms were probably due to the wide differences in the composition of the plant communities themselves, soil surface characteristics, and to differences in the chemical and physical properties of the soils (Fresquez and others 1987). The treeland plant communities had significantly higher fungal populations and a lower diversity of fungal groups, probably a result of the significantly higher organic matter concentrations, plant cover, and litter and decreased amounts of exposed soil compared to the soils from the shrubland or the grassland plant

Table 1--Fungal parameters associated with soils from three major plant life-forms occurring in the semiarid Southwest

Fungal parameters	Treeland	Shrubland	Grassland
Propagules (10^3 /g)	177 a ¹	34 b	32 b
Diversity	0.81	0.86	0.94
Evenness	0.67	0.72	0.76
Dominant groups	<i>Penicillium</i> <i>cyclopium</i> / <i>P. funiculosum</i> / <i>P. unidentified</i>	<i>P. cyclopium</i> / <i>Aspergillus</i> <i>ochraceus</i> / <i>A. fumigatus</i>	<i>Fusarium</i> spp./ <i>A. fumigatus</i> / <i>A. ochraceus</i>
Similarity coefficients			
Treeland		35	44
Shrubland			34

¹ Means within the same row followed by the same letter are not significantly different at the 0.05 level by the Least Significant Difference (L.S.D.) test.

communities. The lower soil organic matter and surface characteristics of the shrub and grassland plant communities probably led to decreased fungal populations, but increases in the number of fungal groups. Some shrub (i.e., Atriplex canescens/Sporobolus airoides - Sitanion hystrix) and grassland (i.e., Gutierrezia sarothrae/Bouteloua gracilis - Hilaria jamesii) communities, however, had lower soil fungal diversities because of adverse soil chemical and physical properties (as opposed to a low fertility status) and/or adverse soil surface conditions that probably resulted in increases in soil temperature and decreases in the amount of available soil moisture.

CONCLUSIONS

Soil fungi (their population size, diversity and community composition) offer a useful method to help delineate phyto-edaphic communities. In this preliminary study, different fungal communities were clearly associated with soils having different plant formations (i.e., tree, shrub, and grasslands). From a resource management perspective, fungal population size and diversity indices may be a useful means of describing ecosystem dynamics (i.e., trends), in terms of identifying more productive soils, and/or identifying or expressing the degree of soil physiochemical stress that is being placed on the soil-plant ecosystem.

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MULTISPECTRAL LANDCOVER CLASSIFICATION:

AN OVERVIEW OF AN OPERATIONAL ALTERNATIVE

Steven J. Gill, Judy A. Hart, and David B. Wherry

ABSTRACT: Over the past two decades resource management agencies have required ever greater amounts of geographic data. The traditional methods used to acquire these data have increased greatly in cost while budgets have become progressively more limited. Landcover classifications based on digital satellite data provide an efficient and cost-effective alternative to costly aerial photo and ground mapping techniques. This paper provides an overview of the methods used to develop a multispectral landcover classification for use in multilayered Geographic Information Systems.

INTRODUCTION

During the past two decades resource management agencies have required ever greater amounts of information to meet mandated management objectives. Over this same period, the cost of traditional data acquisition and analysis methods has increased dramatically, while budgets have become increasingly constrained. The net result of this trend for large-scale land classification and habitat analysis projects is that traditional aerial photography and extensive ground mapping techniques are no longer cost effective, nor feasible in many cases, for accomplishing project goals.

Digital image analysis techniques offer resource management and planning agencies an efficient and cost-effective alternative to traditional resource mapping and analysis methods. Well designed digital databases have several additional advantages. They allow easy update of information in the system, and the database may be queried for diverse applications without costly and time-consuming data replication.

In the Pacific Northwest, a variety of operational land management database projects have taken the form of Landsat based Geographic Information

Systems (GIS). Typically, these databases consist of several dataplanes, including a Landsat based landcover classification; topographic information derived from USGS digital terrain models; roads, streams, trails, etc., digitized from USGS 7.5 minute quad maps; and timber harvest, land ownership, etc., derived from agency maps and records. Once these maps have been converted to digital database format, the GIS may be used to answer a wide variety of complex management and research questions.

THE DIGITAL IMAGE ANALYSIS LABORATORY

Washington State University's (WSU) Digital Image Analysis Laboratory (DIAL) provides systems support, training, project design, and implementation services to a wide variety of users from the scientific, resource management, and administrative sectors. DIAL users include WSU educators and researchers, as well as remote sensing and geographic information system professionals at federal, state, and local agencies and businesses in the Pacific Northwest. DIAL provides experienced consulting, training, and a powerful combination of batch and interactive image processing hardware and software.

DIAL Service Philosophy

The DIAL service philosophy emphasizes the training of individuals to carry out their own image analysis computing applications. A training course introduces the user to image processing concepts, facilities, and accessibility. Initial application work often involves significant consulting support from DIAL staff. Consulting requirements then rapidly diminish with increasing user project work until self-sufficiency is achieved.

This service philosophy is somewhat unique among private and public image processing facilities, most of which make it their business to provide the user with products, not computing support. Generally users are intimately familiar with their own applications and thus have the greatest capabilities in formulating research problems, designing analysis strategies, and generating final products. While situations do arise in which DIAL staff generate products and design analysis strategies, these cases are always driven directly by user specifications.

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DIAL Systems Capabilities

DIAL provides its users with a variety of data capture, processing, and output systems. A combination of image processing, graphics, and product generation capabilities provides a well rounded complement of tools for those interested in image analysis and GIS technologies. These tools include batch/ mainframe image and GIS processing, interactive image analysis and display, interfaces to graphics processing, access to commercial scanning services, X-Y coordinate digitizing, graphics data manipulation, interfaces to image processing, graphics display and plotting, Polaroid photographic products, overnight 35mm slides, and color pen plots.

Mainframe Image Processing--The workhorse of DIAL's image processing capability is the batch-oriented VICAR/IBIS image processing software package. With more than 150 modular functions and running on WSU's IBM 3090-200 mainframe computer system, VICAR/IBIS provides abundant processing flexibility as well as exceptional efficiency (cost effectiveness) in processing large and small image datasets alike. VICAR/IBIS capabilities are accessible to all DIAL users simultaneously on the multi-user mainframe computer. Access is made possible by WSU telecommunications systems linking users at WSU and throughout the Western United States to the DIAL facility in Pullman, Washington.

Interactive Processing--With DIAL's interactive system, users are aided by immediate color display of their image processing results. Within the display/analysis session, images can be previewed, processing strategies can be designed to meet research requirements, and intermediate and final analysis products can be displayed for verification and/or photographic recording. A VAX super minicomputer and specialized image processing hardware provide the computing power which optimizes the real time display/analysis sessions at this WSU-based facility.

AN OVERVIEW OF SATELLITE BASED LANDCOVER CLASSIFICATION

Usually the development of the land classification layer of the GIS is one of the most complex tasks of the database development and it is to this topic that most of this paper is devoted. Once the project study area has been identified, there are several steps to a successful satellite-based classification:

1. Project design
2. Digital data acquisition
3. Ground data acquisition
4. Definition of training statistics through statistical analyses
5. Application of the training statistics through the classification algorithm

6. Assessment and evaluation of the classification
7. Refinement of the classification (if necessary) using ancillary data
8. Assessment and evaluation of the revised classification
9. Integration of the classification with other data planes of the GIS
10. Production of output products

PROJECT DESIGN

There are several points to consider when designing projects using satellite data. These include:

1. The cost/benefit ratio of using Landsat or other satellite technology compared with other data collection methods. The cost savings tend to be most dramatic with relatively large and/or mostly inaccessible study areas.
2. The ability of satellite and ancillary data inputs to provide the required output products. For example, Landsat only "sees" the overstory of heavily forested plant communities. If the project requires information on understory composition, the researcher must be certain that he or she can correlate the overstory cover type with the appropriate understory assemblage. (This can often be accomplished by stratifying the Landsat spectral classification with topographic data, but more on this later.)
3. What types of ground data and ancillary digital data are necessary and available to the project.
4. What types of output products will be required.

DIGITAL DATA ACQUISITION

To date several satellites have been launched that return publicly accessible earth imagery. Most prominent among these are the five Landsat satellites launched by the U.S., and SPOT, which was recently placed into operation by the French. The instantaneous field of view, or picture element (pixel) size, of these satellites varies from 80 meters on a side to 10 meters, depending on the type of imagery used. More details on the Landsat satellites and their data may be obtained in Freden and Gordon (1983), and the September 1985 issue of "Photogrammetric Engineering and Remote Sensing", which was devoted to Landsat Image Data Quality Analysis. Landsat data are available from the EOSAT Corporation, Lanham, MD., and SPOT data from the SPOT Image Corporation, Reston, VA. The Digital Image Analysis Laboratory maintains archived Landsat imagery for all of Washington and portions

of Idaho, Oregon, and British Columbia.

Two types of digital terrain data are available from the National Cartographic Information Center in Reston, VA. The first is U.S. Geological Survey 7.5 minute digital elevation model (DEM) data. These data correspond to USGS 7.5 minute quadrangle maps. The second format is Defense Mapping Agency (DMA) data. These data are available in 1° x 1° blocks. DIAL has a complete set of DMA data for the state of Washington and northeastern Oregon, as well as portions of the Idaho panhandle. Both Landsat and DMA data are available to agencies conducting projects at DIAL.

GROUND DATA ACQUISITION

It cannot be emphasized too strongly that at least one project participant must be thoroughly familiar with the area to be classified using satellite imagery. If this is not the case, gross classification errors will likely occur. DIAL's service philosophy of training individuals and project teams to carry out their own image analysis computing applications does much to resolve this potential problem, as those most familiar with the project area are actively involved in its execution.

DEFINITION OF TRAINING STATISTICS--MULTISPECTRAL CLASSIFICATION

Basic requirements for multispectral classifications are that there exist two or more bands (multispectral components) which are spatially aligned (registered) and that the data analyst performing the classification have an adequate grasp of the imagery through ancillary aids such as ground data and familiarity with the study area or image subject. Landsat MSS imagery provides four bands of data per image and Landsat TM data provides six reflective bands plus a band of thermal infrared data. These data are routinely used in multispectral classification projects, both at DIAL and worldwide.

The principle involved in multispectral classification is called pattern recognition (Castleman 1979). Every object reflects electromagnetic energy (light) in a characteristic set of wavelengths which can aid in distinguishing that object from other objects. The distinguishing set of spectral characteristics of an object are called the object's "spectral signature," or more correctly, its "spectral response pattern" (Hoffer 1979). In digital image processing, spectral patterns are defined using means, variances, and covariances as descriptive statistics. These class statistics are then applied to the multispectral data through a classification algorithm that assigns each pixel to a response pattern class based on the pixel's similarity to that pattern.

There are a number of approaches to the problem of defining the statistical groupings or spectral classes used to classify digital imagery. At conceptually opposite ends are the "supervised" and "unsupervised" methods (Fleming and others

1975; Schowengerdt 1983:142). More familiar analogous techniques are discriminant and cluster analysis, respectively. In the supervised approach, the analyst selects numerous areas of homogenous cover type and specifies these sites as "training" areas. The statistics that define spectral classes for a given cover type are produced by aggregating similar training areas. A final set of classification statistics is obtained by accumulating the statistics for all cover types.

The unsupervised approach utilizes a cluster algorithm which divides multi-dimensional image data into a number of spectrally distinct statistical groupings. In this scheme, the analyst supplies the cluster algorithm with controls such as the number of desired spectral classes, minimum acceptable statistical separability, and an image sampling scheme. The resulting spectral class statistics are used to classify the image data. Identification of the cover type(s) represented by each spectral class is accomplished after the classification is completed.

Numerous approaches to spectral class definition employ variations on the supervised and unsupervised methods. The effectiveness of a given approach depends to a large extent on the nature of the area to be classified. In most remote sensing applications, combinations of the supervised and unsupervised techniques are often advantageously used (Schowengerdt 1983:147-149). Hoffer (1979) outlined six methods and compared them for total cost, analyst and computer time used and accuracy. Traditionally, the supervised technique is probably the most commonly used method, although Hoffer (1979) found this approach resulted in the lowest classification accuracy and had the highest cost per unit area of the methods tested. The technique giving the highest classification accuracy is known as the multi-cluster blocks technique (Hoffer 1979). Fortunately, this method was also one of the least expensive of those tested (Hoffer 1979). The multi-cluster blocks method is a hybrid of supervised and unsupervised clustering techniques. It is similar to the supervised approach in that statistics are developed from training areas of known cover type. The training areas are, however, heterogeneous blocks of data. By judiciously selecting training areas, the analyst can ensure that all significant variations in spectral response for each cover type are represented in the classification statistics. Thus, the major limitations of both the supervised and unsupervised methods are to a large extent overcome. Each of these major approaches to classification statistics are used at DIAL based on individual project requirements. Guidelines for the use of the multi-cluster blocks technique may be found in Gill and Hart (1984).

APPLICATION OF TRAINING STATISTICS TO MULTISPECTRAL IMAGERY

Once class characteristics have been determined, the individual pixels must be assigned to the appropriate category. VICAR provides two programs for making pixel assignments: BAYES, which uses the maximum likelihood algorithm (Hart and Wherry 1984, v. 2:33-35, v. 4:7-8); and FASTCLAS, which

uses the parallelepiped and, optionally, the maximum likelihood techniques (Hart and Wherry 1984, v. 2:97-99, v. 4:31). The maximum likelihood classifier is a parametric approach that requires the calculations for each pixel of the probability that it belongs to each of the defined classes (Hart and Wherry 1984 v. 4:7-8; Schowengerdt 1983:176). This method quantitatively evaluates the variance and correlation of the multidimensional clusters when classifying an unknown pixel (Estes and others 1983:1045). Each pixel is then assigned to the class for which membership is most likely. Because the maximum likelihood method is parametric, it assumes a normal distribution. The parallelepiped method is nonparametric, and thus makes no assumption about class distributions (Schowengerdt 1983:176-177). When FASTCIAS is used under the hybrid parallelepiped/maximum likelihood option, unambiguous pixels are classified with the parallelepiped algorithm and the maximum likelihood algorithm is only invoked to resolve ambiguities when a pixel is located within two or more parallelepiped decision boundaries (Hart and Wherry 1984, v. 2:97-99, v. 4:31).

CLASSIFICATION EVALUATION AND DESIGNATION OF INFORMATION CLASSES

To maximize the usefulness of the classified image, spectral classes must be aggregated into information classes. It is often desirable to define several spectral classes for a single cover type in order to account for the natural variation in spectral response within that cover type. Thus, there are generally several spectral classes assignable to each cover type in the classified image. Therefore, spectrally classified images are simplified by assigning each spectral class to an information class appropriate to the project's information requirements. It is at this point that access to complete and accurate ground data becomes especially important. Enough good data must be available to accurately assign each spectral class to an information class.

Spectral classes often are not uniquely correlated with a desired information category. This can be particularly true in areas of rugged terrain where slope and aspect as well as cover type affect the spectral characteristics of a given pixel. A classic example of this problem is the inability to entirely distinguish water from dark shadows using Landsat MSS data alone. Stratification of the classified Landsat data with terrain data is one technique (discussed later) that can be used to reduce this confusion.

Once the spectral classes have been assigned to information classes, the classification or model of landcover types must be tested for accuracy. A classification error occurs when a pixel is incorrectly labelled; in other words, its information class designation does not agree with the true class observed on the ground. Classification accuracy may often be best represented by a confusion matrix. The level of error typically present will depend on the nature of the cover types to be classified. For example, it is much more difficult to distinguish between spruce and hem-

lock forests than between coniferous forests and grasslands. The acceptable level of error will depend on the project requirements, and may not be the same for all classes. If an acceptable level of accuracy has been obtained at this point, further refinement of the classification using additional data planes may not be necessary. This is often the case when the study area has low topographic relief and/or the desired information requires no discrimination between cover types of similar spectral response patterns. Otherwise, it may be necessary to add additional dataplanes to the classification as outlined below (Eby 1987, Hart and others 1986).

CLASSIFICATION REFINEMENT USING ANCILLARY DATA

Often Landsat data alone are insufficient for constructing an adequate land cover model for a given area. This is especially true in areas having rugged terrain and for landcover types with similar reflectance values such as often occur in the Pacific Northwest and Rocky Mountain states. The addition of data planes containing topographic information can substantially reduce ambiguities (Hart and others 1986; Miller and Shasby n. d.; Strahler and others 1978; U. S. Geological Survey 1979). For example, coniferous forest types are generally very difficult to distinguish using only spectral data. However, many of these vegetation types have elevation, aspect, and slope requirements that can be used to distinguish one type from another within the Landsat classification. After stratification, the revised classification must be checked again for accuracy.

INTEGRATION OF THE CLASSIFICATION AND OTHER DATAPLANES

Once the classification is complete, it can be geometrically corrected to the standardized GIS map base. In this manner multiple dataplanes (roads, streams, elevation, precipitation, etc., as outlined earlier) can be queried simultaneously for any given region within the project area.

OUTPUT PRODUCTS

Output products may take many forms: disk or tape datasets, lineprinter maps, photographic products, plotter output for either vector or raster data, or files downloaded onto diskettes for use with microcomputer-based systems. DIAL supports all of these output options.

CONCLUSIONS

Landsat-based landcover classifications integrated into a comprehensive Geographic Information System offer resource managers and scientists a powerful and cost-effective tool for providing answers to complex questions driven by management and research objectives. A Landsat-based GIS offers the additional advantages of easy information updating and the ability to answer multiple research and management questions without costly and time-consuming

data replication. DIAL's service philosophy recognizes the advantage of agencies performing their own projects, and in the process developing skills for manipulating project databases in an ongoing operational mode. DIAL assists in the integration of the skills and capabilities available in the agency's staff with the expertise and computing facilities offered at Washington State University to guide the agency towards self sufficiency in Landsat and GIS project endeavors.

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UNDERSTORY DEVELOPMENT IN PSEUDOTSUGA FORESTS: MULTIPLE PATHS OF SUCCESSION

Charles B. Halpern and Jerry F. Franklin

ABSTRACT: Vegetation changes after catastrophic disturbance commonly follow multiple pathways, reflecting variation in initial community composition, intensity of disturbance, or availability of propagules. In this paper we examine patterns of understory development during 21 yr of succession in logged and burned Pseudotsuga forests in the western Cascade Range, Oregon. We use detrended correspondence analysis ordination to assess the successional pathways of six forest communities exposed to a gradient in disturbance. We then use Euclidean distances between pre- and post-disturbance samples in ordination space to evaluate the resistance and resilience of communities. DCA ordination reveals multiple paths of succession characterized by 1) initially rapid floristic change away from pre-disturbance composition, followed by gradual return and 2) increasing compositional change with disturbance intensity. Community resistance and resilience reflect interactions between disturbance intensity and the life history traits of dominant residual and invading species.

INTRODUCTION

Catastrophic disturbances such as clearcut logging or wildfire profoundly influence the composition of vegetation. Species comprising a post-disturbance community derive from a variety of sources--wind dispersed seed, on-site or buried propagules, and resprouting survivors. Their ultimate contribution to the seral flora reflects a complex interaction of initial abundance, disturbance intensity, propagule availability, and chance. Thus, in ecosystems subject to large-scale, heterogeneous disturbance, succession commonly follows multiple pathways (e.g., Cattellino and others 1979, Noble and Slatyer 1980). Further, the ability of component species to resist disturbance determines the relative change in community composition; reestablishment from seed or vegetative propagules determines the rate and extent to which initial composition is restored.

In this paper, we examine the response of Pseudotsuga forest communities to clearcut logging

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and slash burning. The data presented derive from 22 yr of observation of permanent plots in the western Cascade Range of Oregon. We first describe how successional pathways vary with initial community composition and with disturbance intensity. We then discuss how these factors influence community resistance to disturbance and long-term recovery, or resilience.

STUDY AREA

The study area, Watershed 1 of the H. J. Andrews Experimental Forest, lies along the western slope of the central Cascade Range, 80 km east of Eugene, Oregon. Elevations range from 442-1013 m and slopes average 50-60%. Soils are derived from tuffs and breccias and are primarily loam textured, moderately stony, and porous (Dyrness 1969). The climate is maritime with mild, wet winters and warm, dry summers. Annual precipitation averages 2302 mm, yet only 6% falls from June to August. Average minimum temperatures range from -5.5°C in January to 11.9°C in August; average maxima range from 5.5°C in January to 23.3°C in July (Bierlmaier and McKee in press).

Vegetation on Watershed 1 (WS1) is representative of the Tsuga heterophylla zone (Franklin and Dyrness 1973). Prior to logging, forest canopies were dominated by mature and old-growth Pseudotsuga menziesii (125 and 300-500 years-of-age, respectively), with Tsuga heterophylla in a variety of age classes. Understory vegetation was composed of six plant communities arrayed along a gradient of available moisture (Table 1).

Table 1.--Characteristics of the six forest understory communities of Watershed 1. Communities are arranged in order of increasing available moisture

Plant Community	Topographic Position	Dominant Species
<u>Corylus cornuta</u> - <u>Gaultheria shallon</u>	ridgetops; S-facing, upper slopes	<u>Corylus cornuta</u> , <u>Acer circinatum</u> , <u>Berberis nervosa</u>
<u>Rhododendron macrophyllum</u> - <u>Gaultheria shallon</u>	ridgetops; mid-slope benches	<u>Rhododendron</u> <u>macrophyllum</u> , <u>Gaultheria shallon</u>
<u>Acer circinatum</u> - <u>Gaultheria shallon</u>	mid- to upper, S-facing slopes	<u>Acer circinatum</u> , <u>Gaultheria shallon</u>
<u>Acer circinatum</u> - <u>Berberis nervosa</u>	mid- to lower-slopes	<u>Acer circinatum</u>
<u>Coptis laciniata</u>	mid- to lower-slopes	<u>Tsuga heterophylla</u>
<u>Polystichum munitum</u>	bottom- and steep, N- to E-facing slopes; seeps	<u>Polystichum munitum</u> , <u>Acer circinatum</u>

METHODS

During 1962, prior to logging of WS1, 134 permanent plots (2 X 2 m) were established, sampled, and assigned to one of six understory communities (Table 1). Within each plot, visual estimates of projected canopy cover (%) were made for all species less than 6 m tall. WS1 was clearcut over a 4 yr period (fall 1962–summer 1966). After logging, plots were resampled (summer 1966), slash was burned (October 1966), and plots were assigned to soil disturbance classes:

1. Undisturbed. Soil surface similar to that of the original forest--little mixing of soil and litter and no evidence of fire.
2. Disturbed - Unburned. Litter removed or mixed with mineral soil, but no evidence of fire.
3. Lightly burned. Surface litter charred by fire.
4. Heavily burned. Surface litter entirely consumed by intense fire.

Post-burning remeasurements were annual for 7 yr and, thereafter, were generally biennial.

Successional pathways were examined by ordinating composite samples through time using DECORANA, a FORTRAN program for detrended correspondence analysis (DCA) (Hill 1979). Composites represent the average cover of each species within each 1) plant community, 2) soil disturbance class, or 3) combination of community and disturbance class for each sampling year. Within each ordination field (e.g., Fig. 1) points representing the same composite sample in successive years were connected sequentially to form successional trajectories. Measures of community resistance to disturbance and long-term recovery, or resilience, were derived from Euclidean distances between composite samples in ordination space. Resistance was defined as inversely proportional to the maximum Euclidean distance between pre- (time 0) and post-disturbance (time x) composite samples. Resilience was defined as inversely proportional to the Euclidean distance between pre-disturbance and final samples (17 yr).

RESULTS AND DISCUSSION

Multiple Pathways

Plant Communities--Ordination of community samples through time reveals a series of distinct successional trajectories (Fig. 1). Communities are aligned initially along Axis 2, generally corresponding with the moisture gradient. Following disturbance, rapid floristic change away from initial composition is followed by slow, unidirectional return. In addition, successional trajectories remain aligned along the initial moisture gradient.

Early post-disturbance patterns reflect the temporary loss of community dominants (e.g., *Acer circinatum* or *Berberis nervosa*) and the establishment of fugitive annuals (e.g., *Senecio sylvaticus* or *Epilobium paniculatum*). Subsequent compositional changes are less dramatic, reflecting gradual shifts in the abundance of rather persistent in-

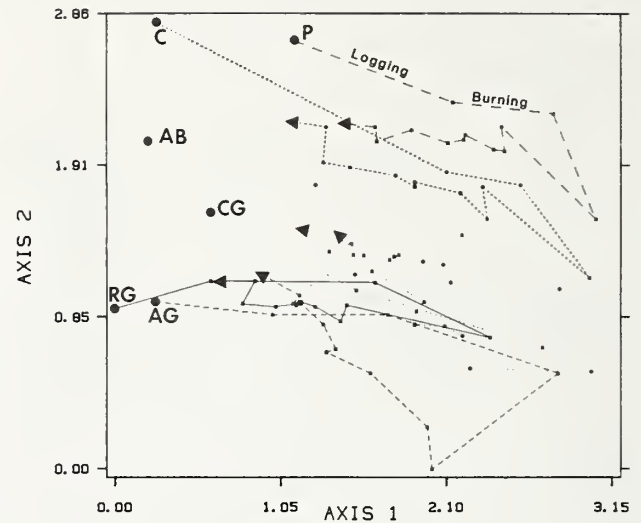


Figure 1.--DCA ordination through time of composite samples representing initial communities. Lines connect the same sample in subsequent years. Closed circles represent initial communities; second and third points represent post-logging and post-burning samples, respectively; arrows coincide with final samples (year 17) and indicate the direction of change through time. Community codes: CG = *Corylus-Gaultheria*, RG = *Rhododendron-Gaultheria*, AG = *Acer-Gaultheria*, AB = *Acer-Berberis*, C = *Coptis*, P = *Polystichum*.

vading and residual species, with varying recovery to initial community composition (Halpern 1987).

Intensity of Soil Disturbance--The intensity of soil disturbance profoundly influenced the magnitude and direction of vegetation change. Ordinations through time of composite samples representing soil disturbance classes reveal increasing compositional change with disturbance intensity (Axis 1, Fig. 2). For example, composition on undisturbed sites (A, Fig. 2) changed relatively little after burning because initial dominants

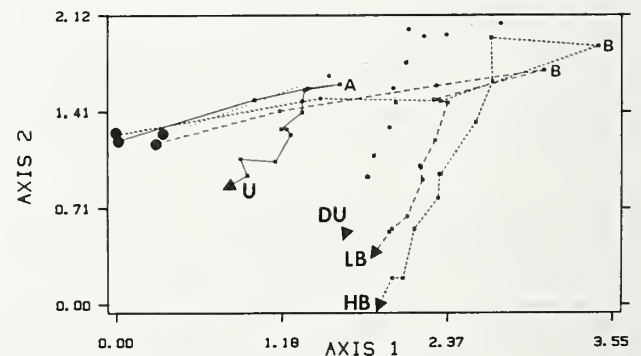


Figure 2.--DCA ordination through time of composite samples representing soil disturbance classes. A and B are referenced in the text. Disturbance codes: U = Undisturbed, DU = Disturbed Unburned, LB = Lightly burned, HB = Heavily burned. See Figure 1 caption for details.

persisted. On lightly and heavily burned sites, in contrast, major changes in composition occurred; sample positions after 2 yr (B, Fig. 2), coincide with the maximum abundance of annual colonizers (e.g., *Senecio sylvaticus* and *Epilobium paniculatum*). Local prominence of these species reflected copious seed production, the interaction of a winter annual life cycle with fall burning, and an affinity for the high soil fertility associated with recent burns (West and Chilcote 1968).

Subsequently, composition changed gradually from herb- to shrub-dominated understories (Axis 2, Fig. 2). Differences in the distribution of residuals and invaders account for the increase in trajectory length with disturbance intensity. For example, undisturbed sites were reoccupied by resprouting dominants (e.g., *Acer circinatum*), whereas disturbed and burned sites were dominated by invading shrubs--*Rubus parviflorus* on disturbed-
unburned sites and *Ceanothus velutinus* and *C. sanguineus* on lightly and heavily burned sites.

Interaction of Initial Composition and Disturbance Intensity--Multiple successional paths may reflect the combined influence of initial composition and

disturbance intensity. For example, where soil was undisturbed, communities generally maintained their initial floristic character through time (Fig. 3A). Successional trajectories are variously directed, occupying small discrete zones within the ordination field. Distances encompassing each trajectory are consistently shorter than those separating them. Two trends account for these patterns: 1) invaders played a minor role on undisturbed sites and 2) original community dominants persisted through disturbance and generally recovered to initial abundance.

In contrast, where soil was lightly burned, communities changed profoundly in response to fire (Fig. 3B). Pre-disturbance samples are aligned along Axis 2, roughly coinciding with the moisture gradient. After burning, however, community trajectories briefly converge due to widespread establishment of invading annuals and temporary loss of forest residuals. Trajectories subsequently diverge as communities display distinct patterns of development (Halpern 1987). Additionally, recovery of original community composition is poorer on lightly burned (Fig. 3B) than on undisturbed sites (Fig. 3A), as indicated by distances separating initial and final samples.

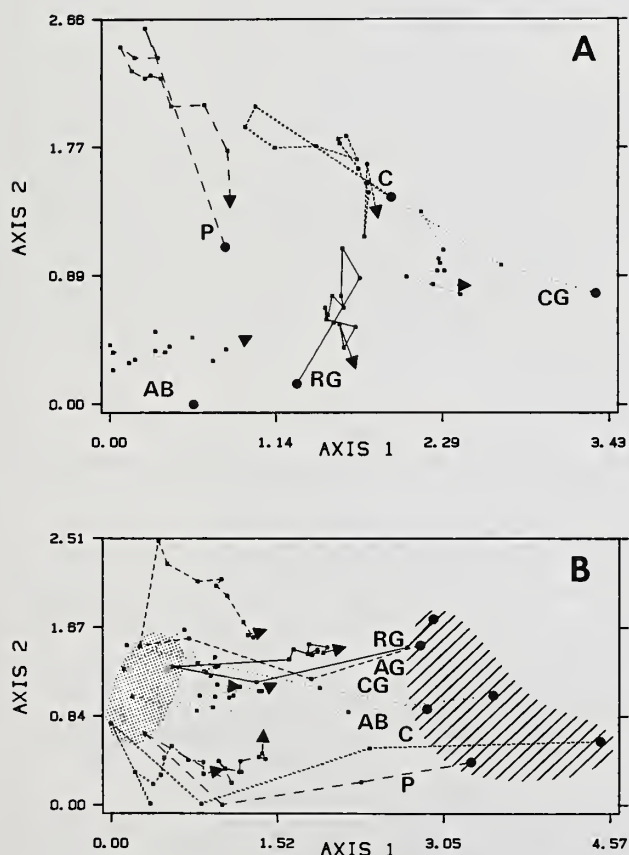


Figure 3.--DCA ordination through time of composite samples representing initial communities on A) undisturbed and B) lightly burned sites. Hatched and stippled areas illustrate convergence from initial (hatched) to post-burning (stippled) composition. See Figure 1 caption for details.

Measures of Resistance and Resilience

Resistance and resilience are measures of the immediate and long-term response of communities to disturbance, respectively. Resistance to disturbance reflects both the persistence of initial species' canopies and the exclusion of invaders. Community resilience derives from the recovery of initial dominants and the elimination of invaders.

Intensity of Disturbance--Both resistance and resilience varied inversely with the intensity of disturbance (Fig. 4). For example, undisturbed

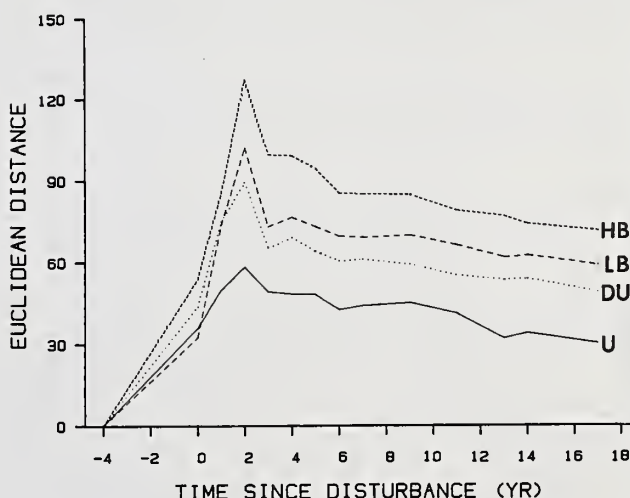


Figure 4.--Changes in Euclidean distance with time between pre- and post-disturbance composite samples representing soil disturbance classes. Times "-4", "0", and "1" represent initial forest, post-logging, and post-burning samples, respectively. See Figure 2 caption for disturbance class codes.

sites displayed high resistance (i.e., small maximum Euclidean distance) relative to disturbed and burned sites. In this system, loss of above-ground structures appears directly related to fire severity. The establishment of invading annuals is also directly related to disturbance intensity. For example, invaders such as *Senecio sylvaticus* may respond to the increased availability of germination sites and of soil nitrogen on burned sites (West and Chilcote 1968).

The resilience of undisturbed sites was also greatest (i.e., smallest Euclidean distance at final sampling). Understory recovery in *Pseudotsuga* forests typically depends on vegetative expansion of survivors, as reproduction from seed appears poor (Haeussler and Coates 1986; Russel 1974). Nevertheless, initial dominants recover more slowly on burned sites than on unburned sites (Haeussler and Coates 1986; Kraemer 1977; Steen 1966), despite an ability to sprout after severe fire. Furthermore, both the magnitude and duration of dominance of the principal invading shrubs, *Ceanothus sanguineus* and *C. velutinus*, increase with disturbance intensity. Because elevated temperatures stimulate germination of its buried seed, *Ceanothus* typically increases in abundance with burning intensity (references cited in Conard and others 1985). Its greater persistence on burned sites may reflect reduced competition from residual shrubs, as well as differences in its establishment.

Plant Communities--Plant communities generally were similar both in their resistance and resilience (Fig. 5). However, the contrast was greatest between *Coptis* and *Polystichum* communities. The *Coptis* type--associated with dense sub-canopies of *Tsuga heterophylla*--is extremely depauperate. Invading species dominated the post-disturbance flora and a paucity of residuals resulted in poor long-term recovery. In contrast, the *Polystichum* type is typically well-developed. Although invaders were briefly dominant, surviving residuals served

as centers for vegetative expansion, promoting relatively rapid community recovery.

Interaction of Initial Composition and Disturbance Intensity--Among disturbance classes, community responses varied dramatically. For example, on undisturbed sites, resistance of the depauperate *Coptis* community was intermediate and resilience was high (Fig. 6A). Surviving *Tsuga heterophylla* reestablished a dense understory tree canopy, largely preempting invaders. In contrast, resistance and resilience were relatively low for lightly burned *Coptis* sites (Fig. 6B). Seral communities were dominated by invaders and by initially uncommon residuals released from competition. Without a well-developed residual flora, long-term recovery after light burning may require canopy closure to eliminate these species. However, formation of a dense *Tsuga heterophylla* sub-canopy will be slower than on undisturbed sites, as re-establishment must be from seed.

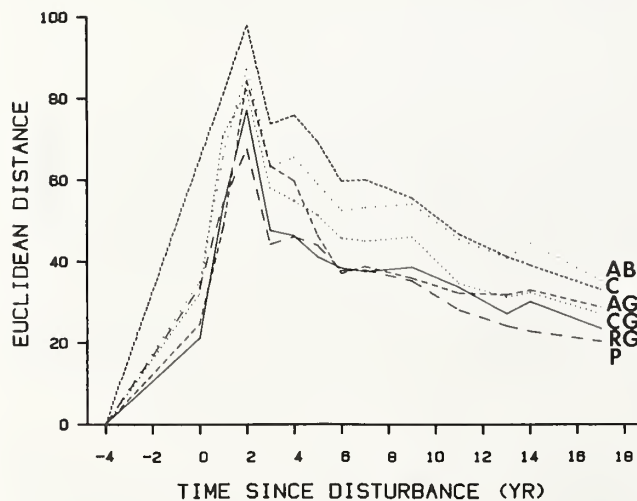


Figure 5.--Changes in Euclidean distance with time for the initial communities. See Figure 4 caption for details and Figure 1 caption for community codes.

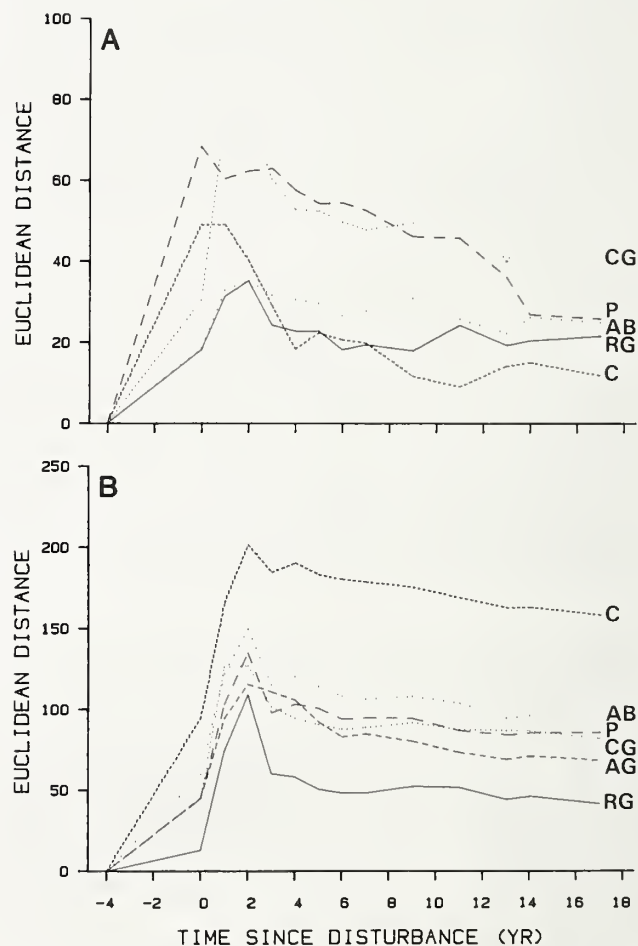


Figure 6.--Changes in Euclidean distance with time for the initial communities on A) undisturbed sites and B) lightly burned sites. See Figure 4 caption for details and Figure 1 caption for community codes.

CONCLUSIONS

Multiple Paths of Succession

Multiple paths of succession were observed after logging and burning of Pseudotsuga forests. Alternate pathways illustrate the importance of initial composition and disturbance intensity in understory development. Community trajectories were rather distinct, characterized by maintenance of the initial moisture gradient and by a gradual return toward initial composition. Alternate paths of succession also resulted from differences in disturbance intensity. The magnitude and direction of compositional change reflected variation in the response of dominant residual and invading species to a gradient in disturbance.

Community Resistance and Resilience

Within the range of disturbance intensities studied, Pseudotsuga communities exhibited an inherent tendency to return toward initial composition. Other authors have termed this trend stability (e.g., May 1973), adjustment stability (e.g., Sutherland 1981), or resilience (e.g., Westman 1978). Recovery from catastrophic disturbance in our system is founded in the moderate resistance of community dominants to logging and burning, and in their ability to subsequently perennate from subterranean structures.

Disturbance intensity largely determined the magnitude of compositional change and the degree of recovery. Initial composition and structure also influenced the resistance and resilience of communities (e.g., depauperate Coptis and well-developed Polystichum types). The interaction of disturbance intensity and initial composition further contributed to variation in the immediate and long-term response of communities to catastrophic disturbance.

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RIPARIAN DOMINANCE TYPE CLASSIFICATION FOR MONTANA

Paul L. Hansen, Steve W. Chadde and Robert D. Pfister

INTRODUCTION

The Montana Riparian Association (MRA) is a cooperative sponsored by federal and state agencies, private organizations, and individuals, located at the University of Montana's School of Forestry. Chartered in June 1986, the first objective of the MRA was to complete a dominance type classification of the riparian plant communities in Montana. This work is being followed by the development of an ecological classification based on site potentials. Data collection and analysis for this second phase are currently under way.

METHODS

Field sampling was conducted in 1985 and 1986 for development of the dominance type classification. Communities were sampled to encompass a broad range of environments. The selection of sample stands was based on "subjective sampling without preconceived bias" as described in Mueller-Dombois and Ellenberg (1974). Plots 50 m² were used to sample homogeneous riparian communities. Dimensions of most plots were 5 m by 10 m, a shape shown to be effective in sampling many riparian communities of our region (Tuhy and Jensen 1982; Youngblood and others 1985; Hansen and others 1987a; Platts and others 1987). Narrow stringer communities, such as those confined to the immediate river edge, were sampled using 2.5 m by 20 m plots. Forested communities were sampled using 375 m² plots (Pfister and Arno 1980).

Within each plot, a complete species list was compiled and unidentified plants collected for later office identification. Estimates of canopy cover (Daubenmire 1959) for each species were made using the following cover classes:

T = 0-1%	4 = 51-75%
1 = 1-5%	5 = 76-95%
2 = 6-25%	6 = 96-100%
3 = 26-50%	

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Soil characteristics were described for each plot. Water regime for the site was estimated and described, with notes taken on water table depths and the occurrence of flooding.

Additional data collected for each sample plot included species composition of adjacent wetter and drier communities, aspect, slope, elevation, and community shape and size. Disturbances such as logging or grazing were noted and current management of the area was described, where possible. Intensity of wildlife use was estimated and ranked as low, moderate, or high.

A stepwise procedure was used to determine riparian dominance types. Unknown plant species were first identified and corrections made to field data sheets. Data sheets were then examined to determine dominant overstory species. Dominance was assigned to those species having at least 25 percent canopy cover in the tallest layer of the sampled community. For example, a community having 30 percent canopy coverage of *Populus deltoides* (a tree), and 80 percent canopy coverage of *Symphoricarpos occidentalis* (a shrub), would be considered to be dominated by *Populus deltoides*. If two or more species in the tallest layer had coverages greater than 25 percent, the species having the greatest cover was considered dominant. If cover values were equal, the species were considered codominant.

Next, field data from other riparian studies in Montana were analyzed to determine dominance types. Site data from these sources were also useful in describing the range of environments associated with each dominance type. In addition, a large body of literature was examined for information regarding the ecology and management of each dominance type. For common, widely distributed species, such as *Populus tremuloides*, a large amount of previous research was available for review. For uncommon species of limited distribution, such as *Carex leptalea*, few data were available.

This information was next assembled into a draft manual suitable for field testing and review by research and management personnel of various agencies and organizations throughout the state. To date, nearly 500 copies of the "Riparian Dominance Types of Montana" (Hansen and others 1987b) have been distributed. The revised, final version will be available in June 1988 as a Montana Forest and Conservation Experiment Station publication.

RESULTS AND DISCUSSION

Following data analysis and literature review, 149 riparian dominance types were described. Twenty-three tree species, 29 shrubs, 61 graminoids, and 36 forb species were identified as dominating riparian environments in Montana.

For each dominant species, a line drawing and distinguishing characteristics were presented, followed by information on its environmental and geographic distribution throughout Montana. Plant species frequently associated with each dominance type were listed and commonly encountered soil types and moisture conditions described. Each species was also assigned a "wetland status" identifier based on a system developed by the U.S. Fish and Wildlife Service (Reed 1986). Management considerations, such as timber and forage productivity, wildlife values, hydrologic characteristics, fire susceptibility, and recreational suitability were discussed. The dominance type descriptions will help resource managers identify and properly manage riparian habitats in Montana.

However, it must be acknowledged that this is only a beginning. Although useful for immediate needs such as inventory, mapping, and broad-scale management, dominance types do not necessarily reflect the potential plant community of a site. A dominance type classification is based simply on the vegetation currently dominating a given unit of land ("cover type"). Classifications that identify potential natural vegetation, as influenced by site characteristics such as soils, precipitation, temperature, and elevation will be of greater value in developing specific recommended management practices. This work, producing an ecological site classification for the riparian areas of Montana, is currently under way by the MRA.

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RELATIONSHIP OF HABITAT TYPE AND RANGE SITE

M. Hironaka

One often hears that each land management agency uses a land classification system that is not compatible with classification schemes of other agencies. This is not so! The agencies do have a unified classification system! The apparent confusion lies with the difference with which the classification units are named as well as the units belonging to different levels in the same classification hierarchy. The range site, ecological site, and habitat type classifications are units from the same classification system. Let me explain.

The range site is a land classification unit based on the climax vegetation and a specific productivity level. An ecological site is synonymous with range site--both are identical, but one land management agency prefers to use range site and another prefers using the term "ecological site" for the same classification unit.

The habitat type is also a land classification unit and it is based on the climax vegetation as is the range site. Separation of one habitat type from another is based on difference in climax vegetation alone and not on difference in productivity level. Land areas that support or supported different climax vegetation belong to different habitat types (fig. 1).

All range sites supporting or capable of supporting the same climax vegetation belong to the same habitat type. Thus, several range sites, each supporting or capable of supporting fundamentally the same climax vegetation are members of the same habitat type (fig. 2). Moreover, each range site within a habitat type is different from another range site in the same habitat type because of difference in productivity capability, although still capable of supporting the same climax vegetation.

This makes the range site/ecological site a subdivision of a habitat type, which is a habitat type phase. In this case, the habitat type phase is based on productivity level. The range site/ecological site is likened to the habitat

type phase based on productivity (fig. 3). Thus, the two classification units, habitat type and range site, are of the same classification system, but are units from different levels in the same classification hierarchy.

ARTRV/FEID Habitat Type Without Subdivision (Phase)

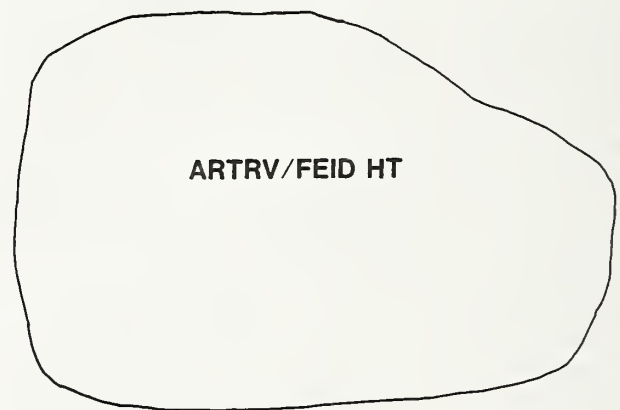


Figure 1--Habitat type is an area of land that supports or supported a specific climax vegetation (plant association). If the area has been disturbed, it is presumed that the area is yet capable of again supporting the same climax vegetation.

Range Sites: Each unit separated on basis of productivity level. All supporting the same plant association (ARTRV/FEID)

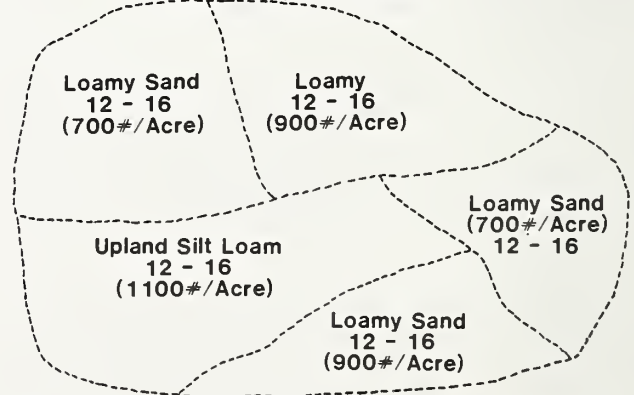


Figure 2--Range site is an area of land different from other areas in that it supports or supported a significantly different kind or amount of climax vegetation.

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Habitat Type Phases Within ARTRV/FEID HT

Conclusion: Range site is likened to habitat type phase
: Both classifications are members of the same system

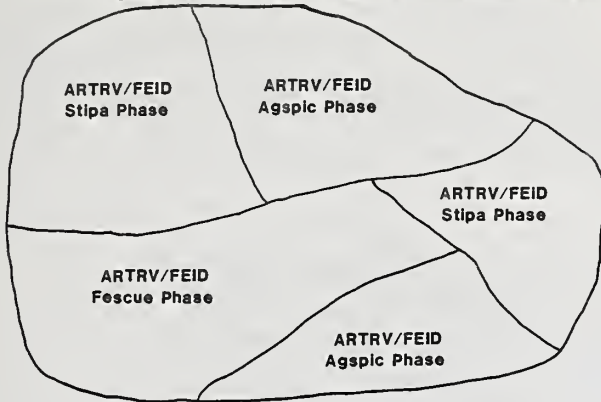


Figure 3--Habitat type phase is a subdivision of a habitat type based on various expressions of the climax vegetation. When the subdivision is based on level of productivity (or soils) the habitat type phase is identical to range site.

Because each range site is associated with a specific group of soils, which in turn is associated with a specific habitat type, each habitat type also contains a unique set of soils. This fact establishes the relationship between soils and habitat type.

Once the relationship between the range site and associated soils has been established, wherever one of the associated soils series is located, the same range site exists. This same basic relationship also exists for the association of the unique set of soils to a specific habitat type.

Thus, each range site is associated with a unique set of soils. This also is the case with habitat type. This establishes the basic soil-vegetation relationship that has been sought by land managers. The relationship is between the climax vegetation and soils, not seral vegetation and soils. That is why the relationship only works with the climax vegetation of the range site and habitat type. It will not consistently work with seral community types, nor when soil classification is performed at the family level.

SOIL-HABITAT TYPE RELATIONSHIPS IN THE TROUT CREEK DRAINAGE, BOUNDARY COUNTY, IDAHO

Kent E. Houston, Maynard A. Fosberg, Kenneth E. Neiman, and Gary Ford

This study compared soil and habitat type classifications along a south-facing elevation gradient in the Selkirk Mountains of northern Idaho. Along this moisture-temperature gradient, the Inceptisol soil order is transitional to the Spodosol order. Corresponding to soil order changes, transitions occur between plant associations of the *Pseudotsuga menziesii*, *Tsuga heterophylla*, and *Abies lasiocarpa* series. The major objective of this poster is to illustrate the concomitance of soil and habitat type information in land classification and management.

STUDY AREA LOCATION AND DESCRIPTION

The study area is located in the Trout Creek drainage of the Selkirk Mountains 15 miles northwest of Bonners Ferry, ID (fig. 1 and fig. 2). Two contrasting geologic substrates occur in this portion of the Selkirks. These are steeply dipping Precambrian metasediments of the Belt Series along the eastern flank and granitics of the Kaniksu Batholith which make up the core of the range. Both substrates have been extensively modified by continental and alpine glaciation. A thin layer of volcanic ash from Mount Mazama (6,700 yrs. BP) Mount St. Helens (150 yrs. BP) forms a mantle over most of these glaciated surfaces.

The climatic regime of northern Idaho is an inland expression of the Pacific Coast maritime climate controlled by high-elevation westerly winds. This results in precipitation primarily in the spring, fall, and winter. Summers are warm and dry, with occasional thunder showers.

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Figure 1--Study area is located 15 miles northwest of Bonners Ferry, ID.



Figure 2--Study site locations along the Trout Creek drainage.

METHODS

Study sites within the Trout Creek drainage were subjectively selected to represent variation in soils and habitat types. Of 30 sites sampled, only three are discussed in this paper. Soils were classified to the family level. This classification was supported by existing laboratory data and soil climate data. Plant canopy cover was estimated for each species found within a 375 square meter plot encircling the soil pit. The climax vegetation or habitat type (h.t.) was identified to the phase level using Cooper and others (1987).

RESULTS AND DISCUSSION

Table 1 summarizes pertinent soil and habitat type characteristics of the following sites.

Site One

Site one is characterized by the Pseudotsuga menziesii/Physocarpus malvaceus h.t. Smilacina stellata phase. Associated soils are: Coarse Toamy, mixed, frigid, Dystric Xerochrepts. The habitat type is indicative of a xeric (low summer precipitation) soil moisture regime and a frigid (cool) soil temperature regime.

Management implications include:

- * Moderate timber productivity
- * Possible significant reforestation problems
- * Light to moderate seasonal cattle use
- * Productive seral stages for big game food and cover requirements

Site Two

Site two is characterized by the Tsuga heterophylla/Clintonia uniflora h.t. Clintonia uniflora phase. Associated soils are: Medial over sandy-skeletal, mixed, Andic Cryochrepts. The habitat type is indicative of udic soil moisture regime (high summer precipitation) and cryic (cold) temperature regime. The presence of a volcanic ash layer (Bs horizons) leads to a higher moisture retention capacity in the surface soil.

Management implications include:

- * High to very high timber productivity with excellent height growth for Pseudotsuga menziesii, Larix occidentalis, and Pinus monticola.
- * High site productivity dependent on the amount of volcanic ash influencing the surface layer; if the surface soil is lost, productivity will decline due to infertile and droughty subsoils.

Site Three

Site three is characterized by the Abies lasiocarpa/Menziesia ferruginea h.t. Luzula hitchcockii phase. Associated soils are Medial over sandy-skeletal, mixed, Entic Cryorthods. The habitat type is indicative of a cryic temperature and udic moisture regime. The soil responding to the colder and wetter environment, have developed albic E (leached) horizons, Bh horizons (accumulations of organic matter), and spodic Bs horizons (accumulations of Fe and Al oxides).

Management implications include:

- * Low timber productivity
- * Forest regeneration and productivity

- limited by cold temperatures, high elevations, and short growing seasons
- * Regeneration problems associated with high shrub coverage
- * Site productivity depends upon the amount of volcanic ash influencing the surface layer; if the surface soil is lost, productivity will decline due to infertile and droughty subsoils

Table 1--Summary of site characteristics

Characteristic	Site 1	Site 2	Site 3
Elevation	638m	1350m	1850m
Habitat type & Phase	Psme/ Phma Smst	Tshe/ Clun Clun	Abla/ Mefe Luhi
Soil order	Incept.	Incept.	Spodosol
Soil moisture	Xeric	Udic	Udic
Soil temperature	Frigid	Cryic	Cryic
Diagnostic horizons	Ochric	Ochric	Albic
Horizonation sequence	Cambic	Cambic	Spodic
E and Bh development	0, Bw, C	0, Bs1, Bs2, IIC	0, E, Bh, Bs1, Bs2,
Ash influence	None	Some-Weak	Strong
NaF pH	None	Strong	Strong
Substrate	8.8	10.3	10.8
	Till	Ash	Ash
	Metasedimentary	Till	Till
		Granitic	Granitic

CONCLUSIONS

The Trout Creek study illustrates that habitat types are a good method of extrapolating soil moisture and temperature regimes. Both of these characteristics are instrumental in the classification of soils to the family level.

The soil and habitat type relationship is naturally quite complex. This complexity requires soil scientists and plant ecologists to work together to optimize landscape delineation and to predict management responses. This would result in more useful and precise baseline data and classifications than if they were developed independent of each other.

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HABITAT TYPE CLASSIFICATION SYSTEM FOR NORTHERN WISCONSIN

John Kotar, Joseph Kovach, and Craig Locey

Although in the western United States the habitat type classification systems have been developed in almost every state and are now a common tool for evaluating biological potential of forest sites, the habitat type concept has not been used widely east of the Rockies. The only exceptions, to our knowledge, are the system developed for the Upper Peninsula of Michigan by Coffman and others (1983), and the system for northern Wisconsin presented here (Kotar and others, in press).

Perhaps the main reason few ecologists have attempted this type of vegetation classification in the east is the lack of readily perceived floristic differences, usually associated with strong elevation gradients and rugged topography. This certainly is the case in the Lake States. In addition, good examples of "old growth" forests are practically nonexistent.

Nevertheless, our work, as well as that of Coffman and his associates, showed that distinct associations can be recognized if reasonably mature stands (>50 years) are sampled across a range of sites and proper association analysis techniques are used. In Wisconsin and Michigan the different soils, associated with various types of glacial landforms, exert a strong influence on floristic composition of forest communities and provide a good basis for habitat type differentiation.

Our classification system for northern Wisconsin is based on relevé analysis of over 800 stands. We used the same sampling techniques as those commonly applied in many western studies, except that our plots were rectangular instead of circular. A 21x21 meter macroplot was divided into six subplots for estimating plant coverage. In order to simplify the use of identification keys and to allow for more specific local description of the habitat types, we divided northern Wisconsin into five regions (fig. 1).

Regional divisions were based on physiography, soils, climate, and certain floristic discontinuities. The natural boundaries between these regions could not be delineated precisely because soil, climate, and flora boundaries are almost always gradual, and they probably never coincide. Therefore, whole counties were grouped into regions in such a way that each region could be characterized by at least one major natural feature. A total of 17 habitat types and seven series were delineated for the five regions (table 1).

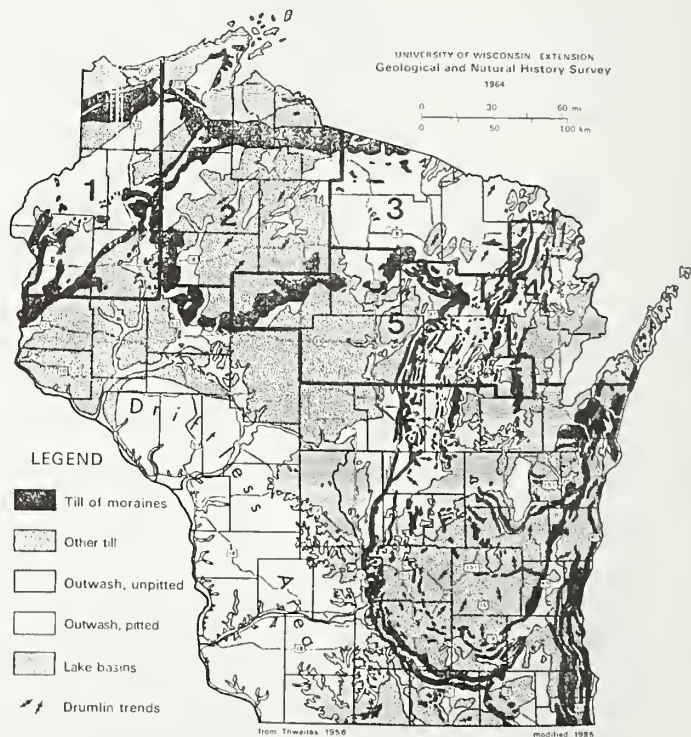


Figure 1--A map of glacial deposits of Wisconsin showing five regions delineated for present classification.

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To further examine ecological relationships among various habitat types and their distribution along local environmental gradients, we subjected the relevés to a two-dimensional ordination using moisture and nutrient indices (synecological co-ordinates) developed by Bakuzis (1959). Bakuzis assigned each forest species a value of 1-5 to indicate the species' requirements for each of four site factors: moisture, nutrients, heat, and light. For example, a species with moisture index

Table 1--Forest habitat types of northern Wisconsin by series

Quercus ellipsoidalis series		
Quercus/Gaultheria-Ceanothus h.t.	QGCe	
Quercus/Amorpha h.t.	QAp	
Acer rubrum-Quercus rubra series		
Quercus-Acer/Epigaea h.t.	QAE	
Acer-Quercus/Vaccinium h.t.	AQV	
Pinus strobus series		
Pinus/Amphicarpa h.t.	PAm	
Pinus/Maianthemum-Vaccinium h.t.	PMV	
Acer saccharum-Tsuga canadensis series		
Acer-Tsuga/Dryopteris h.t.	ATD	
Acer-Tsuga/Maianthemum h.t.	ATM	
Acer saccharum-Fagus grandifolia series		
Acer-Fagus/Dryopteris h.t.	AFD	
Acer saccharum series		
Acer/Vaccinium-Desmodium h.t.	AVDe	
Acer/Vaccinium-Viburnum h.t.	AVVib	
Acer-Quercus/Viburnum h.t.	AQVib	
Acer/Atherium h.t.	AA	
Acer/Viola-Osmorhiza h.t.	AViO	
Acer/Hydrophyllum h.t.	AH	
Acer/Caulophyllum-Circaea	ACaCi	
Tsuga candensis series		
Tsuga/Maianthemum-Coptis h.t.	TMC	

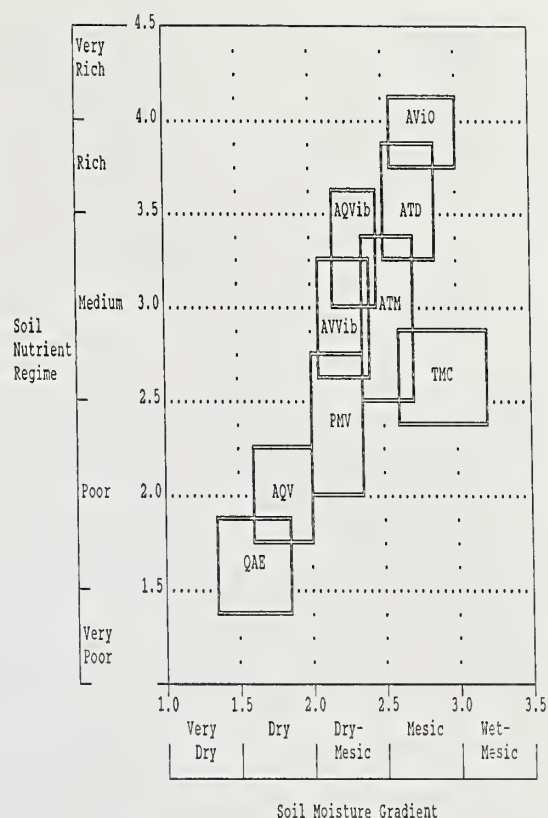


Figure 2--Relationship of nine habitat types of Region 3 to soil moisture and nutrient regimes.

of 5 occurs primarily in very wet environments. A species with a nutrient index of 1 occurs primarily on sterile, sandy soils. Bakuzis derived preliminary values for these indices from the literature and adjusted them through field measurements. An estimate of these environmental factors for a given site is obtained by calculating a mean index from the individual indices of all species present on that site.

We used the moisture and nutrient indices to calculate and plot the means for all relevés in our data set. The relevés, representing different habitat types, formed distinct clusters with some overlap among the most similar types. Figure 2 is a semi-quantitative representation of habitat type distribution on a moisture-nutrient grid for Region 3. The rectangles were drawn so that they enclose at least 90% of the relevés representing each habitat type. We arbitrarily assigned qualitative terms to segments of moisture and nutrient axes to provide better visual interpretation of the physical environment of various habitat types.

If all relevés representing the 17 habitat types that occur in the five regions are plotted on a single graph, considerable overlap among habitat types exists, as would be expected. This happens because many habitat types in one region may be considered as "ecological equivalents" of other types in other regions. These "ecological equivalents" occupy similar positions on the moisture-nutrient gradient in their respective

regions, but their floristic composition differs sufficiently to be recognized as distinct associations.

In figure 3, the overall mean of the nutrient index is plotted against the soil moisture index for all habitat types. The habitat types in numbered clusters are ecological equivalents and overlap significantly if all relevés are plotted, but little or no overlap exists between the types in different clusters.

Although the habitat types in each cluster are different enough to require the development of individual management techniques, they can be treated as a unit for general planning purposes. For example, AH, ACaCi, and AViO habitat types in Cluster 1 represent the highest productivity sites for northern hardwoods in their respective regions. They all tend to be heavily dominated by sugar maple, but the importance of various associated species differs. On the other hand, AVDe and AVVib in Cluster 4 represent sites where the role of sugar maple is at its minimum. Although it is the most shade-tolerant tree, and is presumably capable of dominating at climax, the site conditions are not adequate for its optimal growth, and therefore, the succession proceeds much more slowly than it does on the previously mentioned types. Instead, early and mid-successional stages tend to be dominated by red oak and red maple, and are relatively stable.

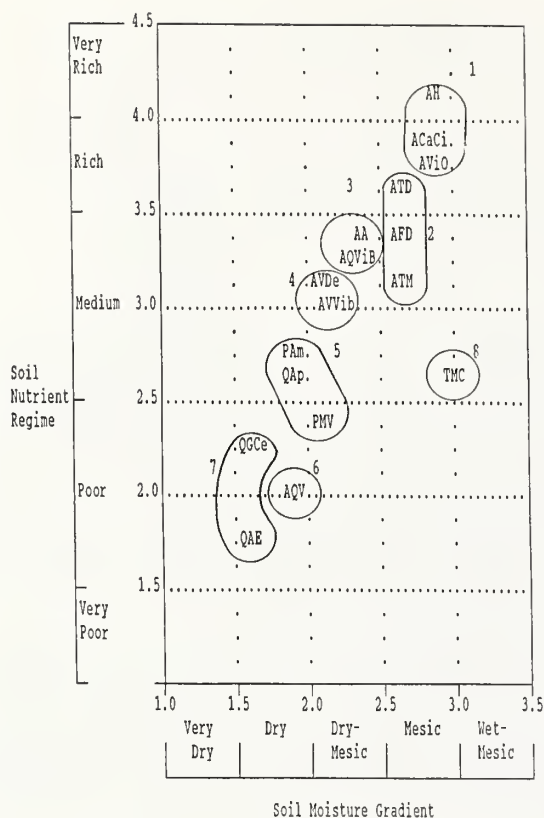


Figure 3--Relationship of all habitat types of northern Wisconsin to soil moisture and nutrient regimes. Numbered clusters are habitat type groups with similar management implications.

A field guide to this classification system has been completed and will be published in early 1988. It will contain the following information: identification keys; descriptions of important habitat type characteristics; successional diagrams; and a discussion of management implications for each type. Color illustrations of plants needed to identify the types will also be included.

The Field Guide can be obtained through the Department of Forestry, University of Wisconsin, Madison, 1630 Linden Drive, Madison, WI 53706. Cost \$44 (includes postage and handling).

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THE VEGETATION CLASSIFICATION AND DATABASE
OF THE MONTANA NATURAL HERITAGE PROGRAM

Andrew M. Kratz

The Montana Natural Heritage Program (MTNHP) was established by the State of Montana and The Nature Conservancy in 1985 to create a comprehensive statewide database on Montana's biological diversity. MTNHP is working on information acquisition, storage, and retrieval for data relating to the flora, fauna, and natural plant communities of Montana. Information on the existence, location, numbers, condition and status of rare and endangered plants, animals, and natural vegetation is collected and made available to all interested parties. MTNHP is one of nearly 50 Heritage Programs in the United States.

One of the program's tasks has been to assemble a comprehensive list of Montana's climax and seral natural vegetation types (plant associations, plant communities). The list of types has been arranged in the classification hierarchy developed by the United Nations Educational, Scientific, and Cultural Organization for the vegetation of the world. This framework separates forests from shrublands and herbaceous vegetation, then further subdivides each class into subclasses, groups, and formations. Below the formation level, MTNHP has listed series and then associations. This structure enables the MTNHP vegetation classification to be integrated with classifications developed by other Heritage Programs, and facilitates the exchange of information between states.

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The MTNHP vegetation classification was developed through an extensive review of published and unpublished sources, including papers on habitat typing, journal articles, theses, and dissertations, as well as other "gray literature" such as private industry reports for environmental impact statements. These various papers describe vegetation for specific areas within the state, but the classification and database developed by MTNHP link these many separate sources to provide a statewide perspective.

The database includes information for each vegetation type on its distribution within Montana and site characteristics (slope, elevation, aspect, and soil). It also has comments on phases and successional relationships, as well as citations for the literature describing each type.

There are several useful aspects of the classification and database. They provide a foundation for the development of a comprehensive statewide guide to the vegetation of Montana. They enable Heritage Program staff to focus information collection activities on the most poorly described or threatened vegetation types in the state. They facilitate information exchange between states with similar types of vegetation. Coupled with MTNHP's site location database, they can provide information to public land managers and the private sector on the location and ecological status of Montana's most threatened vegetation types, thereby facilitating better management of these valuable resources.

The vegetation classification and database are dynamic. They will be amended or supplemented as more information on Montana's natural vegetation becomes available.

MAPPING AND APPLICATION OF PLANT ASSOCIATIONS FOR FOREST PLANNING:

TONGASS NATIONAL FOREST, ALASKA

Jon R. Martin and Thomas DeMeo

THE TONGASS NATIONAL FOREST

The Tongass National Forest is located in the Alexander Archipelago, southeastern Alaska. It is the largest National Forest in the United States, extending over more than 16.8 million acres. The forest encompasses an area 400 miles long and 100 miles wide and has a total coastline in excess of 11,000 miles.

Southeastern Alaska has a cool and moist maritime climate. Precipitation ranges from a recorded low in Skagway of 26 inches to a high in Little Port Walter of 211 inches per year. On the average, cloudy skies occur on 275 days per year. Average maximum temperature during the growing season range from 54 to 65 °F. Soil drainage, temperature variation along elevational gradients and soil disturbance caused by flooding, windthrow, and mass wasting are the dominant factors influencing the vegetation within southeastern Alaska. Fire is not an important factor and most of the forested land is in an old growth, climax condition.

THE PLANT ASSOCIATION PROJECT

The plant association (PA) classification work began as a pilot project in 1981 in northern southeastern Alaska. Since that time, about 3,000 forest stands have been sampled throughout southeastern Alaska. Seven series (Tsuga heterophylla, Tsuga heterophylla-Chamaecyparis nootkatensis, Tsuga heterophylla-Thuja plicata, Picea sitchensis, Tsuga mertensiana, Pinus contorta, and Mixed Conifer) and 45 forest PA have been described. We estimate that an additional 10 to 20 forest PA will be described.

A draft classification for the northern portion of southeastern Alaska was produced in 1985. Draft classifications for the central and southern

portions will be printed in May of 1988. Final publications for these three areas should be published in 1988 and 1989. Currently there are four forest ecologists working full time and three soil scientists working part-time on the project.

Future efforts will focus on the classification of riparian and non-forest plant communities and implementation of existing forest PA classifications.

MAPPING PLANT ASSOCIATIONS

PA are mapped in conjunction with a soil and geomorphology mapping project. Mapping criteria were established to delineate as many vegetative attributes as practicable considering map scale constraints and management needs. Mapped units range in size from 20 acres to several hundred. Several similar PA may occur in any particular mapping unit. This will depend on the size and homogeneity of the vegetation and site within the mapping unit.

Field mapping was done on 4 inch/mile color aerial photographs. Field map verification and data collection were done by teams consisting of a soil scientist and plant ecologist prior to producing the final maps.

Mapped photo lines are digitized for use in a geographic information system (GIS). The GIS provides the capability to easily display the distribution and abundance of PA at a stand or watershed scale.

USING PLANT ASSOCIATIONS IN THE TONGASS FOREST PLAN

PA provide a useful descriptive and predictive management tool for silviculture and fish and wildlife habitat management. PA in the first revision of the Tongass National Forest plan will be used to describe the vegetative characteristics of fish and wildlife habitat in the climax, old-growth condition. Since most of the forest land in the Tongass National Forest is in this condition, PA can readily be used to estimate current habitat capability. PA are particularly valuable for describing the quality and quantity of forage in the understory of climax, old-growth stands. They are also useful for characterizing hiding/thermal cover properties for deer winter

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habitat, snag quality and quantity for cavity dependent species, and for describing large organic debris input potential along forest fish streams.

As we improve our understanding of successional patterns over the landscape, the usefulness of PA as a predictive tool for fish and wildlife habitat will increase. This will provide a basis for modeling changes in animal communities over time resulting from past and future changes in the vegetation mosaic.

PA with soils, landforms, and channel types were combined to develop a hierarchical classification of the streamside riparian ecosystem on the Tongass National Forest. Since PA reflect the characteristics of the environment, they provide a useful means of describing the riparian ecosystem. Management of this ecosystem is becoming increasingly more complex due to the high

resource values and the increased public awareness. Consequently, land managers need a more complete understanding of this ecosystem than was previously demanded. To accomplish this, the riparian ecosystem must first be described and inventoried. The approach just described will be used in the Forest Plan revision to inventory the riparian ecosystem.

The PA map on the GIS will provide an inventory of sites with silviculture problems or opportunities. Standards, guidelines, and prescriptions for management of many different sites will be written by PA. Regeneration problems due to flooding, shrub competition, poorly drained soils, and short growing seasons at high elevations can be evaluated. Estimates of timber productivity by species can be made. This information will provide the data needed to develop site specific land management prescriptions and to estimate management costs.

GIX: A PC-BASED GEOGRAPHIC INFORMATION SYSTEM (GIS)

Toru Ottawa

ABSTRACT: A raster-based geographic information system named GIX is being developed for personal computers. This paper summarizes its design philosophy and highlights system capabilities. It also includes a case study demonstrating the application of GIX to preliminary habitat type modeling.

INTRODUCTION

Many GIS systems were developed in the early 1980's in response to the introduction and promulgation of relatively inexpensive personal computers. However, most of them used the same level of software technologies as ones developed on mainframes and mini-computers and did not really take advantage of the potential of personal computers in many respects as will be discussed later. To improve upon the existing PC-based GIS, a new generation of software is being developed by the author.

GIX is a family of software routines primarily designed for the IBM(tm)-PC, PC-XT, PC-AT, PS/2 and their compatibles running under MS-DOS(tm), and is written mostly in the ANSI-standard C language. The underlying philosophy of this endeavor is to develop a user-friendly, low-cost system and yet powerful enough to be able to use in professional projects. Some of the advantages of GIX include the following: (a) extremely user-friendly (b) low capital outlay (c) many analysis capabilities comparable to large, expensive systems, (d) data compatibility with many mainframe and mini-based systems, and (e) easy transportability to other operating systems such as UNIX(tm) and OS/2(tm).

MAJOR SYSTEM FEATURES UNIQUE TO GIX

Error Handling and User-Friendliness

One of the major drawbacks of the existing PC-based GIX routines is that they do not handle user input errors correctly in many cases. In other words, if a user enters a wrong command or a set of data,

then his/her program might lead to system halt. Author's preliminary investigation shows that only a few among many PC-based GIS systems receive high rating in this regard. GIX was designed so it accepts only the type of entry that its particular routine is anticipating from a user. If the user enters a wrong data type, then it prompts to the correct type of entry or terminates the user's program. Or, where appropriate, pop-up menus are used to reduce possible user errors.

Internal Data Type

Many PC-based GIS such as pMAP and CRIES use 2-byte integer data. The fact that they cannot handle floating point data poses a serious problem for users in the scientific community. In other words, on these systems 1.4 plus 1.4 becomes 2, for example, because of truncation. To avoid such inconveniences, GIX uses the double-precision data type (i.e., 8-byte) for its internal data structure. Conversely, however, this approach has some limitations in that the speed of data input-output could be reduced and additional data storage might be required because of the inherent nature of this data type.

Data Compatibility

There are basically two data format types in GIX: GDF and DBF. The former is a file type for individual data layers, for example, soils and vegetation types, while the latter is provided for dBASE III (tm) compatibility. Once all the data layers are prepared the user can pack them into the DBF type. One file can contain as many as 128 data layers or fields. Users of dBASE III or clones can perform very complex analyses using this file. In particular its relational capability could be fully utilized, if more than 128 fields are to be analyzed.

The GDF files can be created either from digitizing or from downloading existing data on mainframe or mini-based GIS such as MOSS, COMARC, ERDAS and ARC/INFO. The main requirement for the latter is there should be an export utility routine converting binary to the ASCII format on the host side. GIX has several data import routines to modify a variety of data formats for its use.

Query Capability

Using the aforementioned DBF file the user can perform very complex query on the data base using logical combinations--AND, OR and NOT. Its results can be quickly shown directly on screen with the system's graphic display program. Very few raster-based GIS have this capability at this point in time.

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USES IN RESOURCE PLANNING AND MANAGEMENT

GIX enables resource managers to analyze in an objective manner primary data layers (e.g., soils, habitat types, cover types, and geology) in small-scale land management and planning. A number of "guesstimate" situations could be eliminated with GIX thanks to the data which provide planners with accurate information on resource distribution patterns. Actual tasks of land managers would then shift from mechanical work (e.g., drafting and shuffling of maps) to data management and interpretations.

GIX could also be used for the detailed assessment of environmental impacts for timber, range, recreation, and mining, once the existing resource data are converted into digital format. Another application may be to aid in the development of mapping unit design for soil and habitat type mapping by using its basic topographic programs for slopes, aspects, elevation and solar radiation index. In addition, its query capability could be applied to vegetation modeling and a number of other tasks that land managers routinely perform.

To demonstrate the applicability of GIX four data layers were digitized from the Idaho Panhandle National Forests: elevation, soils, vegetation types, and grizzly bear habitat types. Slope and aspect files were then directly computed from the elevation file using SLOPE and ASPECT routines in GIX. This area encompasses 4 square miles (i.e., 2 x 2 miles) (fig. 1). Once their editing was complete, they were packed into a DBF file. Then geo-query module in GIX was applied to conduct preliminary examination of the ALBA/VASC habitat type using the following demonstration criteria: elevation ≥ 6000 feet, slope $\geq 20\%$, and aspect between 45 and 315 degrees (fig. 2). With 160 x 160 data cells it required approximately 3 minutes for this task on an 8mhz IBM(tm) PC-AT with an 80287 and 640KB of RAM.

CONCLUSIONS

GIX provides resource managers with an excellent tool for geographic data analyses. In particular, in addition to many analytical capabilities it has

a unique query and database management capability which is not present in most of the raster-based GIS for personal computers. Because of its user-friendly environment, it is also a good tool for training and education. Above all its cost performance can really be appreciated once it is applied to a small-scale land planning and management project.

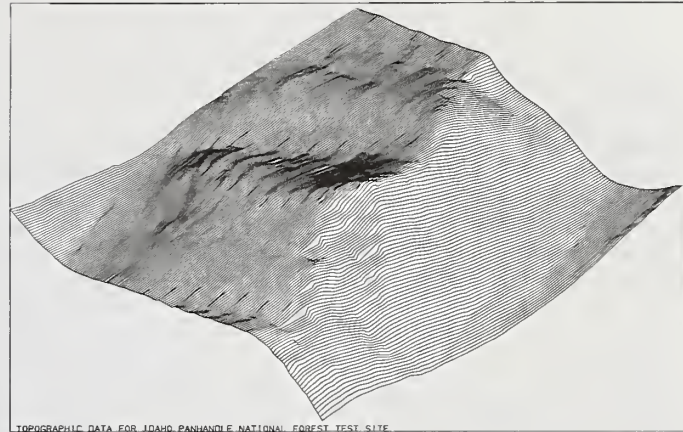


Figure 1--Aerial view of study site.

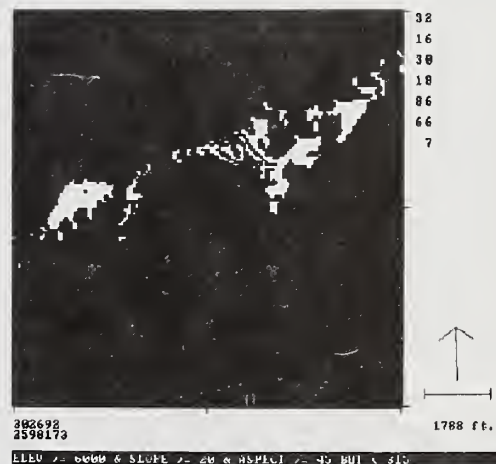


Figure 2--Preliminary assessment of ABLA/VASC habitat type using geo-query module. White areas satisfy criteria applied.

REFORESTING FLOOD-PLAIN SITES IN INTERIOR ALASKA

Andrew P. Youngblood and M. Joan Foote

ABSTRACT: Regeneration research on the flood plain of a major river in interior Alaska is designed to examine the effect of silvicultural system and site preparation, and to determine the effect of vegetation type, on natural and artificial regeneration of white spruce. Preliminary results suggest the need to refine silvicultural prescriptions by vegetation type.

INTRODUCTION

Flood plains along major rivers in interior Alaska support productive forests of white spruce (*Picea glauca* (Moench) Voss) and associated hardwoods. Historically, these forests were exploited for cordwood during the gold rush and settlement period of the early 1900's, when large steam-powered sternwheelers delivered supplies and equipment to mining operations. With establishment of the Tanana Valley State Forest in 1983, the Alaska State Division of Forestry has increased utilization of these forests. Flood-plain forests of white spruce present unique challenges for timber management because of apparent changes in site productivity as soil temperatures decrease (Dyrness and others, in prep.), seasonal access, ineffective silvicultural techniques for slash disposal and site preparation, cyclic seed production, and the rapid regrowth of competing vegetation. Forest managers in interior Alaska lack sufficient information on the best methods for regenerating white spruce.

This paper reports preliminary results of regeneration research conducted on three typical flood-plain vegetation types. Objectives were to assess the effects of various silvicultural systems and practices and determine the effect of vegetation type on artificial and natural regeneration of white spruce.

METHODS

The study area is located on Willow Island, a 210 hectare (520 ac.) island in the Tanana River about

32 kilometers (20 mi.) southwest of Fairbanks, Alaska (lat. 64°50'N, long. 148°0'W). Previous work (Foote 1983; Viereck and others 1984) indicated both stand structure and species composition of stands on Willow Island were typical of flood-plain forests along the lower Tanana River. Thirteen broadly defined plant communities have been recognized (Dyrness and others, in prep.), ranging from herbaceous communities in abandoned sloughs to multi-aged stands of white and black spruce (*Picea mariana* (Mill.) B.S.P.). Three communities dominated by mature white spruce (hereafter referred to as sites) were selected to receive different combinations of silvicultural treatments. Pretreatment species composition, stand structure, and soil attributes are summarized in table 1.

Seven shelterwood and seven clearcut blocks, totaling 22 and 34 hectares (54 and 85 ac.) respectively, were whole-tree logged in January and February, 1983. Zasada and others (1987) described snow conditions and winter logging techniques. Five of the seven shelterwood blocks contained about 100 residual stems per hectare (40 stems per ac.) following logging; this logging treatment is referred to as SW-1. A lower density of stems was retained in the two remaining shelterwood blocks (SW-2). These two blocks may resemble a seedtree cut with only 50 residual stems per hectare (20 stems per ac.). Site I contained a single clearcut block, Site II contained eight blocks (three clearcut, three SW-1, and two SW-2), and Site III contained five blocks (three clearcut and two SW-1).

Mechanical scarification, using a dozer blade or pulled Bracke-type patch scarifier, was applied to 30 by 60 meter (100 by 200 ft.) plots in all but two cutting blocks during the summer of 1983. An adjacent plot of equal size received no scarification, and served as a control. Thirteen hectares (32 ac.) in two clearcuts not receiving mechanical scarification on Site I and III were broadcast burned in July, 1983 (Zasada and Norum 1986).

Each site preparation plot was split to receive one of three artificial regeneration treatments; planted seedlings, protected seeds, or unprotected seeds. Putman and Zasada (1986) have previously detailed techniques for protecting seed from adverse environmental stresses using plastic cone and funnel shelters. Nursery-reared containerized white spruce seedlings (1-0 stock, seed source Willow Island) were planted on a 2.4 by 2.4 meter (8 by 8 ft.) spacing in June, 1983. At the same time, about 8 to 10 uncoated white spruce seeds

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Table 1--Species composition, stand structure, and soil parameters for three sites on Willow Island, Alaska

	Site I	Site II	Site III
Vegetation (percent cover)			
<u>Picea glauca</u>		20 - 50	30 - 60
<u>P. glauca</u> and <u>P. mariana</u>	15 - 25		
<u>Betula papyrifera</u>	5 - 15		
<u>Alnus crispa</u>		10 - 60	< 5
<u>Alnus tenuifolia</u>		1 - 50	20 - 80
<u>Rosa acicularis</u>	10	10 - 25	5 - 20
<u>Ledum groenlandicum</u>	30		
<u>Linnaea borealis</u>	5	15	20 - 40
<u>Vaccinium vitis-idaea</u>	50	10 - 50	0 - 15
<u>Equisetum arvense</u>	15 - 40	2 - 40	0 - 20
<u>Hylocomium splendens</u>	40	20 - 70	60 - 90
<u>Pleurozium schreberi</u>	20	< 5	
<u>Rhytidiadelphus triquetrus</u>		0 - 30	
Other Mosses	15	20	5
<u>Peltigera apthosa</u>	5 - 25		
Stand Structure			
Tree ages (yrs.)	130 - 250	130 - 350	110 - 150
Average stand diameter (cm)	15 - 16	20 - 40	25 - 35
Basal area (m ² /ha)	13	27 - 38	19 - 31
Volume (bdft./ac.) ¹	9,000	12,000	14,000
Density (stems/ha)	500 - 600	300 - 800	250 - 550
Site Index (100)	< 50	70 - 90	80 - 90
Soil Characteristics			
Litter/decomposing moss (cm)	15 - 25	5 - 23	0 - 16
Humus (cm)	0 - 1	0 - 3	0 - 3
Silty to sandy loam (cm)	> 37	35 - 60	25 - 80
Drainage	Poorly drained	Well-drained	Well-drained
Particle size	Silt loam over loamy sand	Silt loam over sandy loam	Silt loam over sandy loam
Permafrost ² (cm)	37 - 70	Intermittent	Free

¹Scribner Dec. C.

²Depth of seasonally active thaw zone.

(same seed source) were direct seeded on "seed-spots". Seed-spots on an unscarified site preparation plot (controls) were protected by small plastic funnels, while seed-spots on scarified plots were protected by plastic cones. Finally, seed was sown on seed-spots lacking protection. From each site preparation plot fifty seedlings or seed-spots from each regeneration treatment were randomly selected for monitoring successful artificial regeneration.

Natural regeneration was monitored on twenty 4 meter squared (30 ft.²) plots receiving patch scarification or broadcast burning on all three sites.

Establishment (survival) and third-year height growth increment were recorded in 1987 for 4800 planted and direct seeded seedlings. Analysis of variance using percent survival with an arcsine transformation and third-year height growth increment as single dependent variables was used to test for significant differences between logging method-site preparation-regeneration

method treatment combinations. Sites were considered unreplicated experimental units with separate analyses conducted for each site.

RESULTS

Natural regeneration of white spruce was sporadic on Willow Island following logging. Broadcast-burned blocks contained more seedlings established after 1983 than advanced regeneration, and apparently provided the best seedbed for germination and establishment of natural seedlings.

Percent survival of artificial regeneration is summarized in table 2. Preliminary analysis indicated little difference between cutting methods (clearcut, shelterwood-1, and shelterwood-2 on Site II, $F = 3.85$, $p < 0.097$; or clearcut and shelterwood-1 on site III, $F = 28.01$, $p < 0.034$). Both site preparation and regeneration method affected survival; survival of planted seedlings after three years was generally

Table 2--Percent survival of artificial regeneration after three years, by logging method, site preparation, and regeneration method, for three sites on Willow Island, Alaska. N represents the number of regeneration plots, each containing fifty seedlings or seed-spots. SE is the standard error of the estimated mean

Treatment	Site I			Site II			Site III		
	Percent survival	N	SE	Percent survival	N	SE	Percent survival	N	SE
CC ¹ BL ² PL ³	97.8	4	4.79	96.4	3	5.15	97.1	2	5.29
CC BL SP	62.0	4	4.79	43.8	3	5.16	55.3	2	5.29
CC BL SU	31.7	4	4.79	71.5	3	5.16	47.0	2	5.29
CC PA PL	98.2	4	4.79	98.3	3	5.16	97.9	2	5.29
CC PA SP	56.4	4	4.79	63.2	3	5.16	73.1	2	5.29
CC PA SU	30.9	4	4.79	74.9	3	5.16	36.0	2	5.29
CC NS PL	99.6	4	4.79	97.8	3	5.16	94.2	2	5.29
CC NS SP	10.8	4	4.79	17.7	3	5.16	37.9	2	5.29
CC NS SU	4.6	4	4.79	27.7	3	5.16	0.5	2	5.29
SW1 BL PL				98.7	3	5.16	99.5	2	5.29
SW1 BL SP				72.8	3	5.16	75.6	2	5.29
SW1 BL SU				79.2	3	5.16	85.5	2	5.29
SW1 PA PL				99.8	3	5.16	99.0	2	5.29
SW1 PA SP				71.5	3	5.16	58.7	2	5.29
SW1 PA SU				70.9	3	5.16	68.4	2	5.29
SW1 NS PL				99.5	3	5.16	98.5	2	5.29
SW1 NS SP				29.7	3	5.16	24.8	2	5.29
SW1 NS SU				25.3	3	5.16	7.0	2	5.29
SW2 BL PL				99.5	2	6.32			
SW2 BL SP				31.1	2	6.32			
SW2 BL SU				53.0	2	6.32			
SW2 PA PL				99.9	2	6.32			
SW2 PA SP				40.2	2	6.32			
SW2 PA SU				72.5	2	6.32			
SW2 NS PL				99.5	2	6.32			
SW2 NS SP				22.0	2	6.32			
SW2 NS SU				23.2	2	6.32			

¹Logging method: CC, clearcut; SW1, shelterwood level 1; SW2, shelterwood level 2.

²Site preparation: BL, bladed; PA, patch scarification; NS, no scarification.

³Regeneration method: PL, planted; SP, seeded with protection; SU, seeded without protection.

above 95 percent, while germination, establishment and survival on seed-spots, regardless of protection, was less than fifty percent. Seeding without protection generally resulted in similar survival as seeding with protection. Site preparation contributed to higher germination and survival of seedlings, but had little effect on survival of planted seedlings.

After three years, mean height growth increment for artificial regeneration (table 3) was greatest for planted seedlings regardless of site preparation. ANOVA indicated no difference between cutting methods on Site II or III ($F = 0.35$, $p < 0.722$ for Site I; $F = 7.32$, $p < 0.114$ for Site III). Annual growth apparently differs by site preparation and regeneration method; all site preparation and regeneration effects and interaction terms were significant. In addition, growth was also affected by vegetation type or site, as shown in table 4. These data suggest

the need to restrict timber management to sites represented by Site III, and to emphasize containerized seedling reproduction with complete site preparation rather than spot seedings.

Recognition and management of timber resources by vegetation or site types that partition the variability in productivity and survival of regeneration may reduce costs associated with silvicultural activities.

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Table 3--Third-year mean height growth increment, by logging method, site preparation, and regeneration method, for three sites on Willow Island, Alaska. N represents the number of seedlings measured for each mean; SE is the standard error of the estimated mean

Treatment	Site I			Site II			Site III		
	Increment (cm)	N	SE	Increment (cm)	N	SE	Increment (cm)	N	SE
CC ¹ BL ² PL ³	4.4	200	0.15	6.3	150	0.23	10.5	100	0.27
CC BL SP	1.4	200	0.15	1.2	150	0.23	1.8	100	0.29
CC BL SU	1.1	200	0.15	1.4	150	0.23	1.2	100	0.29
CC PA PL	4.1	200	0.15	5.7	150	0.23	8.6	100	0.28
CC PA SP	1.1	200	0.16	1.3	150	0.24	2.5	100	0.27
CC PA SU	0.8	200	0.15	1.0	150	0.23	1.1	100	0.27
CC NS PL	3.9	200	0.15	4.1	150	0.23	5.1	100	0.27
CC NS SP	0.1	200	0.15	0.3	150	0.23	1.5	100	0.28
CC NS SU	0.3	200	0.14	0.2	150	0.23	0.0	100	0.28
SW1 BL PL				8.4	150	0.24	8.8	100	0.27
SW1 BL SP				2.6	150	0.23	2.1	100	0.28
SW1 BL SU				2.2	150	0.23	2.2	100	0.27
SW1 PA PL				5.4	150	0.23	6.7	100	0.27
SW1 PA SP				1.8	150	0.24	1.1	100	0.27
SW1 PA SU				1.4	150	0.23	1.0	100	0.27
SW1 NS PL				3.6	150	0.23	5.7	100	0.27
SW1 NS SP				0.3	150	0.23	0.3	100	0.27
SW1 NS SU				0.2	150	0.23	0.1	100	0.27
SW2 BL PL				5.5	100	0.28			
SW2 BL SP				1.6	100	0.29			
SW2 BL SU				1.3	100	0.28			
SW2 PA PL				4.8	100	0.28			
SW2 PA SP				1.4	100	0.29			
SW2 PA SU				1.4	100	0.28			
SW2 NS PL				6.3	100	0.28			
SW2 NS SP				0.4	100	0.29			
SW2 NS SU				0.7	100	0.29			

¹Logging method: CC, clearcut; SW1, shelterwood level 1; SW2, shelterwood level 2.

²Site preparation: BL, bladed; PA, patch scarification; NS, no scarification.

³Regeneration method: PL, planted; SP, seeded with protection; SU, seeded without protection.

Table 4--Mean growth increment (cm) by site and regeneration method

Regeneration method	Site I	Site II	Site III
Planted seedlings	4.1	5.6	7.6
Seedlings - Protected	0.8	1.2	1.5
- Unprotected	0.7	1.1	0.9

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Includes 43 papers and 24 poster synopses that discuss the theoretical
concepts of classification based on vegetation and present practical
applications of various classifications. Papers focus primarily on
classifications for the western United States and western Canada.

KEYWORDS: plant associations, habitat types, succession, diversity, ecology,
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